# THESIS.

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# The Value of the Internal Structure of Fossil Corals as an Aid to Classification.

BY

W. K. YEAKEL,

For the Degree of Bachelor of Science in the College of Natural Science.

UNIVERSITY OF ILLINOIS.

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# P R E F A C E.

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The object of this thesis is to show

(1) that the present method of classifying fossil corals according to external characteristics is insufficient and unsatisfactory;

(2) that the only scientific way is by a study of internal as well as external structures.

Specimens of fossil corals were obtained from S.A.Miller Cincinnati, Ohio. These were determined and labelled by him and represented thirty four species and seventeen genera.

Photographs were made of the specimens in the rough. Next, longitudinal and transverse sections were made into microscopic slides. Enlarged photographs of these sections were made by transmitted light. All these photographs were mounted on the accompanying "plates", a detailed explanation of which is appended.

The essential part of the thesis proper consists of a critical and detailed study of the structure both internal and external, as shown in the photographs, and a comparison with the descriptions as given by various authorities.

As a preparation and aid to this comparative study there was first written a detailed description of both the living coral and its fossil remains and the relations which these two bear to each other were shown.

By this study and comparison the relative values for purposes of classification of the various internal and external characteristics have been made to appear.

It is further shown that the modern classification of this group is indefinite and unsatisfactory.

The conclusion of this investigation is that the internal structure of fossil corals is an essential to definite classification and description of species.

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# THE STRUCTURE OF CORALS.

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The term coral is applied to the calcified secretion of the skeletal portion of the individuals belonging to the class Actinozoa. The Actinozoa are defined as "Coelenterate animals having the mouth opening into an oesophageal tube, which in turn opens below into the general cavity of the body but is separated from the body wall by an intervening 'perivisceral space' divided into compartments by radiating vertical membranous partitions or mesenteries. They are with or without a secreted skeleton."

The calcareous secretions of some of the Hydroids, the Bryozoans, and even of Algae are often designated as coral, but strictly speaking we can consider only those as corals which fall under the above described class.

That we may better understand the skeletal remains of this class of animals, their structure and way of development, we must study the structure of at least that part of the polyp which is intimately connected with the production of the calcareous matter.

The living polyp in its simplest form - that of the Sea-anemone - has the structure of a more or less extended cylinder (Plate I., Fig. 1), one end of which (f) is completely closed and usually forms the place of attachment, called the "pedal disc" or aboral surface. The other end (b) of the body contains a somewhat elliptical opening (a), the mouth surrounded by one or more rows of hollow tentacles (c). This end is known as the head or oral surface. The tissue making up the living portion of the animal consists of an external layer, the "ectoderm"; an internal layer, the "endoderm"; and an intermediate layer, the "mesoderm". The entire outer surface is covered by the ectoderm, and at the oral end drops into the mouth cavity and forms the lining for the oesophageal tube. From the oesophagus downward the internal cavity of the body is lined by endoderm. The mesoderm lies between these two layers and is principally connective tissue giving stability to the upper portions of the body of the animal. The tentacles, Pl.I., Fig. c; Pl. II., Fig.2, t., are hollow, muscular, and tactile, and are placed in one or more rows, around the mouth serving as the animal's prehensile organs. They are usually uniform in size and shape and are always bilaterally symmetrical. Like the body wall, they are composed of three distinct layers.

The mouth is usually elliptical, rarely circular, and has the appearance of a mere slit when closed.

In the polyps of the Hydrozoa the mouth leads directly into the body cavity but in the Actinozoa there intervenes between the body cavity and the mouth a more or less developed tube, forming the oesophagus, Pl. I., Fig. 2, o; Pl. II., Fig. 2, G., the length varying in different species; this tube being formed by an infolding of the ectoderm and endoderm.

From the Oesophagus the opening leads into a much enlarged cavity called the "body cavity", also known as "gastric cavity" or "visceral chamber", Pl. I., Fig. 2,i. This cavity is subdivided into radiating compartments formed by the infolding of the endoderm and mesoderm perpendicularly to the body wall, and longitudinally with the body of the individual. These infoldings, known most commonly as mesenteries, are directed toward the center, extending into the gastric cavity the entire length of the body. The compartments thus formed reaching from the oral end to the pedal disc are but narrow channels leading from the body cavity below to the tentacles above. Surrounding the oesophageal tube the mesenteries coalesce with the tube. Beneath this however, the edges of the mesenteries are perfectly free. (Pl. II., Fig. i, left hand figure, illustrates an ideal transverse section of the mesenteries and body wall through the region of the oesophagus; the right hand figure shows a section through the body below the oesophagus; in the one the edges of the mesenteries are united with the oesophageal tube, in the other they are free.)

The mesenteries in the same individual do not necessarily extend the same distance toward the central axis. Some are much longer than others yet there seems to be a regularity in the arrangement of those of the same development. Those extending farthest toward the center are called the "principal" or "primary" mesenteries, those next longest "secondaries", and so on according to the extent of their development. It is quite generally accepted that the oldest mesenteries are those extending farthest toward the center.

The number of mesenteries varies in different species as it does in the different individuals of the same species, the older ones having a greater number than those of a less age. There is, however, a regularity in the number developed, there being usually 4, 6, 8, or multiples of these numbers. In the Tetrecoralla the mesenteries are principally in multiples of 4; the Alcyonaria the characteristic number is 8; in Antipathidae, 6; In Hexacoralla and Actinaria mostly in multiples of 6.

The number of mesenteries in the individual may readily be determined by nothing more than diverticula from the inter-mesenteric chambers at the oral disc. Each Tentacle then alternates with a mesentery and they are therefore of the same number.

As to the method of reproduction in corals, the young originates either from the fertilized ova which are attached to the faces of certain of the mesenteries toward the lower end of the body or by gemmation and fission. By the former method the individuals are set free and lead an independent life, but by the latter method buds may be given off at various points in the lower portion of the animal. Sometimes these become detached from the mother polyp becoming independent, but in the majority of cases the young individual remains attached to its parent and in turn itself sends off buds which also remain connected. In time a "polyp stock" is formed which may attain various forms and sizes.

The Actinozoans are largely in such a colonial state, united more or less with each other, forming a branched stem as is illustrated Pl. III., Fig. 1. In such colonies, as a rule, the individuals are imbedded in a common body mass, the "coenenchyma", and the gastric cavities are more or less connected with each other by means of canalicular openings through the body wall, communicating with the neighboring individuals. The fossil remains of these animals are principally the result of a calcareous secretion carried on within the body of the polyp. It is almost entirely a secretion, yet there may be deposits caused by the decay of some of the animal tissue which, uniting with certain ingredients in the sea water, in which the animal lives, produces a calcareous deposit.

The calcareous secretion of the coral exists in most diversified forms, ranging from detached microscopic spicules, scattered within the soft tissue of the individual to those having a solid regularly developed corallum. There seems also to be a more or less uniform gradation of these calcifacations. In some of the Actinozoa, as the Sea Anemone or Ctenophora, no calcareous deposits are found, the body of the animal remaining perfectly soft. As referred to before the lowest type of secreted calcareous material is found in the form of detached microscopic spicules found principally among the Alcyonarians. A higher type is seen in the fusion of these spicular developments into a coherent mass forming a true skeleton for the animal, as is seen in the organ-pipe corals. In the Red Coral the spicules become more completely fused forming a solid cylindrical calcareous axis independent of the polyps themselves. This axis constitutes what is commonly called "sclerobasic" corallum, being secreted within the animal. In a great majority of the coralligenous Actinozoa, and those affording the greatest variety of forms and structures for study, the corallum is the direct result of a calcareous secretion of the outer surface of the ectoderm. Such corals are known as "sclerodermic". (Pl. II., Fig. 2).
This last type is the one with which we shall deal principally and hence we will study its structure more fully.

It may be noted in the beginning, that there is a peculiar regularity in the growth of the various developments of the sclerodermic corallum; from the time the young polyp begins its calcareous secretions until it reaches a mature stage, as well as during the life of the mature animal. During the latter period the growth is uniform in all its parts, while in the former period certain forms of the skeleton are developed first, followed by others.

The earliest calcareous secretions by a typical simple sclerodermic polyp is from the ectoderm of its place of attachment, being the aboral surface.

This developes laterally from a central point and upward. The lateral development being usually more rapid soon forming a disc or plate-like skeleton, which is called the "foot-plate", or "basal-plate". From this foot-plate there follow vertical developments, radiating from the center in the form of ridges called "star-ridges". These ridges are developed by a special secretion of certain of the ectodermal cells. As these star ridges develop upward, forming vertical radiating plates, they take the name of "septa". (Pl.II. Fig. 2, s p, also the dark radiating lines Fig.3).

These septa are found to alternate with the mesenteries of the polyp, (Pl.II., Fig. 2, sp and me. Also Fig. 3, s and m.) being developed between two of them.

The "theca" forming the cylindrical and outermost calcareous development, arises much like the septa, excepting that it arises principally from the coalition of the lateral developments occurring near the peripheral ends of the star ridges, and principally from the upward development of a circular wall along the outer edges of the pedal disc. (The general plan of septa and theca is illustrated Pl. II., Fig. 3, s, the radiating septa with the thickened developments near the periphery, meeting each other, and with the upward development along the edge of the pedal disc, forms t, the theca.)

It may be noted here that the theca forming the principal portion of the skeleton greatly protects the polyp and holds firmly the outer edges of the septa, thus consolidating the skeleton in every way.

The theca usually forms the foremost portion in the skeletal development, forming a sort of rim to a shallower or deeper cup shaped depression. (Pl. IV, Fig. 2; Pl. VIII Fig. 2). This depression is termed the "calyx". Sometimes the theca is so developed as to divide the gastric cavity into an outer peripheral portion, and a central portion, the two being in communication with each other above the free upper edge of the theca. In this way two separate developments may arise, the one outside the theca, called "epitheca" that within the theca, the "endotheca". The only epithecal developments of any importance are vertical ridges on the exterior, which correspond with the septa within. Pl. VII., Fig. 1; Pl. VIII, Fig.1 Pl. XI. Fig. 1. These are known as "costae". In some cases, however there are external developments to the theca which are quite different in nature from the costae and which do not correspond with the septa within, but frequently alternate with them. The costae vary considerably in different species, when present; as to their distance apart, the height of their development, solidity and ornamentation, which may be in the form of granules, tubercles, or teeth. In the endotheca of the coral, a great many structures are met with besides the septa themselves; these are primarily considered out-growths from, or modifications of the septa. By a careful study of some of the common corals we find, besides the denser median line occupying the position of septa, very delicately constructed fibrous out growths making a secondary layer known as "stereoplasm" (Pl.XXVI. Fig. 4 st. Pl. XXVII, Fig. 1, st.) This is a calcareous secretion evidently formed some time after the primitive septa, making the septa, or at least parts of it, much thicker. Such a secretion is often noticeable on the theca as well, adding considerable thickness to its outer wall.

In such corals as Favosites the septa are more or less rudimentary in their development, sometimes without a trace of their existence, (Pl. XXXII, Fig. 2 and 5; and Pl. XXXIII. Fig. 2 and 3) often represented merely by ridges, Pl. XXX. Fig. 1 and 2, or rows of spines. (Pl.XXXI. Fig. 2 and 6, sp).

, The septa in some cases are developed upward to a considerable distance above the upper margin of the theca and in their development toward the center they vary from short ridges to broad plates reaching the center. (Pl. XXVI. Fig. 2; Pl. XXVII, Fig. 1.)

Where the septa extend to the center of the individual the central area may become filled with a reticulated, irregular mass, (Pl. XXVII, Fig. 1.), or more or less regularly twisted together giving the appearance of a Columella. The Columella may be considered in some cases to be formed in the above described way, but it is usually a distinct central development, formed by a special calcareous secretion in the axis of the polyp (Pl. II. Fig. 2, co. Pl. XI, Fig. 2 co. and Pl. XXVI, Fig. 5). Typically it extends from the bottom of the visceral chamber to the floor of the calyx, projecting upwards into the latter and having the primary septa usually closely connected with it. (Pl.XXVI, Fig. 4.).

Another special vertical development in the coral is that of the "pali"; These are narrow plates secreted at the inner end of certain septa, not continuous with them but often appearing so. The Columella and pali when both are developed are usually united.

In certain corals, as Diphyphllum, (Pl.XXII, Fig. 3 and 4) we find an inner as well as outer wall. The inner wall marks the limit of the development inward of the primary septa, and separates the central area from an outer zone, bearing the septa. This inner wall has sometimes a small radius or it may closely approach the outer wall, making the outer zone narrow.

The spaces between the septa are usually known as "interseptal spaces", or "loculi". These spaces are often interrupted by various developments. The adjacent septa are often connected by horizontal bars called "synapticula". These are very numerous in some species, while in others they are but slightly developed.

In place of these bars, and connecting the faces of adjacent septa, are thin plates, called "dissepiments". These may be horizontal (Pl. XXII, Fig. 2 and 3) or even vertical (Pl.XXIV, Fig.2 or at any angle between the two positions (Pl.XXVIII, Fig. 1 and 2). They may be perfectly flar, or more or less uniformly curved.

This convexity has its own peculiarity in the species bearing such developments. In Pl.XXII, Fig. 5, we find such structures quite uniform throughout the individual, in others, as Pl.XXIV, Fig. 2 or 4, the spaces formed are irregular in size as well as shape, though the latter figure shows the shapes to be quite uniform.

If any of the so formed spaces are larger, they are usually near the peripheral portion of the corallum. These dissepiments need not necessarily be between the septa, and in cases where no septa are present, may fill the entire inner area of the coral, as shown in Pl. XXIX., Fig. 1 and 3.

If we imagine a transformation or state of development in which this dissepimental tissue becomes more uniform in its occurrence, being on the same plane throughout the individual, and principally horizontal, we have in mind what we call "tabulae". In Pl. XXVIII., Fig. i. we can scarcely tell which is dissepimental tissue or which tabular, showing how indistinct the two structures are.

On the same plate, Fig. 2, there is a clearer distinction. In Pl.XXIV Fig. 4, it is quite difficult to determine just where one begins and the other ends. While in Pl.ZZIII, Fig. 4, Pl. XXXII. Fig. 3 and 4 they are prominently developed and extend from wall to wall, separating the visceral chamber into a series of compartments, one above the other. The living portion of the polyp is always above the last formed cycle of tabulae.

In some cases the tabulae are more or less funnel shaped nicely fitting into each other, as is noticeable in Syringopora, Pl. XXIII. Fig.4.

Tabulae are often highly developed where septa are absent or poorly developed. This is noticeable especially in the Section, Madreporaria perforata.

As has been noted before in many forms of the Colonial polyps, the individuals are attached to each other, or communicate with each other, by means of fleshy ligaments. In such cases, where the calcareous walls are developed, the walls must necessarily be in a perforated state depending upon the number and arrangement of the ligaments. This is a very noticeable characteristic among the perforata of the Madreporarian corals. These perforations are often very regularly arranged in rows. Pl. XVI. Fig. 1, Pl.XXX.Fig. 1, p, Pl. XXI, Fig. 5., and at times also very irregular.

An important factor in regard to the irregular development of some of the septa has not been referred to, and may well be mentioned here. In many of the Rugose Corals we find the symmetry to be more or less bilateral, on account largely of the presence of a shallower or deeper groove or pit, the "fossula", occupied by a limited number of septa of reduced size. Pl. VIII., Fig. 2; Pl.X., Fig. 2; Pl. XI., Fig. 1, (2-3).

Sometimes more than one fossula may be present (Pl. XII. Fig. 1) and the position of the pit this named varies in different types, being sometimes dorsal, sometimes lateral, and sometimes ventral.

In regard to the "Compound Corallum" we may say that it is principally a reiteration of the simple corallum, an aggregate skeleton of a colony of polyps, varying greatly in size. Such a compound corallum, is the result generally of the way in which the young polyp springs from its parent and remains united with it and its neighbors during development. Such a union is usually accomplished in one or two ways, either directly through its walls by fleshy ligament, or by a common calcareous tissue secreted by the coenosarc, which serves to cement the adjacent corallites together. This special secretion is shown as the "Coęnenchyma". Of course the compound Corallum is originally very simple, springing from a single bud or ovum, and becomes composite from the fact that either budding or fission takes place in such a way that a colony is formed.

There are five principal methods by which this increase is effected,-

1st.- by "Lateral or Partial Gemmation", which is the throwing out of a bud or buds somewhere between the base of the polyp and the base of the circle of tentacles.

If numerous buds are thus given off a dense and compact corallum will be the result. On the other hand, if the buds are but

few and far between the result will be a branched form of corallum;
2nd.- by "Calycine" gemmation.

This takes place from the calycine disc of the parent corallite. This mode of gemmation may be either a single simple corallite springing from the calyx forming a succession of inverted cones placed one above the other with the living one uppermose, or, a number of young individuals may spring from the calyx of the parent producing one or more new corallites. Pl. VII, Fig. 1.

3rd.-by "Intermural" gemmation. (Pl.III, Fig. 2).

This sort results from the lip of the parent instead of from the actual calyx itself. This gives the corallite a sort of wedge shaped appearance in a vertical section, as shown in Pl.III, Fig. 2, cut B, co.

4th.- by "Basal" or "Stolonal" gemmation.

This form is common among the Alcyonarians and shows a method in which the original polyp sends forth from its base, prolongations, stolon-like in nature, which give rise to the new corrallites. The Aulopora are illustrations of this method of gemmation. In such cases the peripheral forms of a colony are the youngest corallites.

5th.- by "Fission". (Pl. III, Fig. 3);

This way of multiplication begins by a partial cleavage of the parent polyp. The cleavage begins by a division taking place along one side (P), which continues farther and farther toward the opposite side of the animal until it is finally separated into two individuals.

By a careful study of both the living polyp and its skeletal remains, certain things may be known of the former from that of the latter. There are certain relations existing between the two, among which may be noted principally the following,-

1st.- The septa correspond in number to the mesenteries, and alternate with them.

2nd.- The tentacles of the polyp are superimposed upon the intermesenterial spaces, one above each space, hence a tentacle for each septum, and placed directly above it.

3rd.- The regularly arranged costae correspond usually in number to the septa, and are an indication of the number of septa (if developed) within.

4th.- The interseptal tissue bears no relation to any of the external developments of the coral whether the living polyp or the skeletal remains.

5th.- The method of reproduction can largely be determined by the corallum, whether it be by liberating the ova, by gemmation, or by fission; according to the relation existing between the individual corallites.

# VALUES FOR CLASSIFICATION.

A well established system of classification of any class or order of the animal or vegetable kingdoms is a most essential feature in that branch of the science. It is a noteworthy fact that the system of classification among the corals is still very defective. This is due to the fact that we have but the skeletal remains and their forms to deal with, which in many cases are very unsatisfactory, having but a few values upon which to characterize the species. Were the living polyp present, a more satisfactory classification could readily be made because a greater number of characteristics would then be present, and a wider range for classification would be possible. Not having the living polyp to study in connection with the skeletal remains it is necessary to observe most carefully those values which are still available in classification.

Without doubt, the more general characteristics must serve to determine the more general divisions in the class, while the minuter individual characteristics must serve to restrict the individual to its particular generic or specific place. It seems necessary then, to arrange the values according to the order of their general importance.

It is true that many species may be recognized by experts at sight. Their intuition and experience enables them to seize upon details of external structure which correlate with internal peculiarities and hence make a fairly accurate determination but with a large number of specimens the external features are certainly insufficient for an accurate identification even by experts; and nothing but a careful examination of all the values will be sufficient for accuracy in classification.

For convenience we may consider the values as <u>external</u> and <u>internal</u>.

# E X T E R N A L   V A L U E S.

The external values for classification may, primarily be grouped under four heads.

1st.- General shape and size of the corallum, whether conical cylindrical, or compressed; and whether large or small. There are instances )Lothostrotion canadense, Pl.VI, Fig. 2, and L. proliferum Pl. VII. Fig. 1.) where in the same genus, one species is compressed and another is cylindrical, showing shape to be of value only in specific descriptions. The same is true in regard to size.

2nd.- Relation of Individuals. Corals live either solitary or in colonies, but since the same genus may have members in both forms (Cyathophyllum houghtoni, Pl.IV, Fig. 1, and C, davidsoni, Fig.2) this also can not be considered a very important value except for description of species. In the compound form there exists in the same genus a great range in the compactness of individuals. Some are very loosely united (Syringapora, Pl. XVIII, Fig. 2 ), while others are so closely arranged as to form a solid mass. (Emmonsia, Pl.XVIII, Fig. 1.)

3rd.- Ornamentation of External Surface.

External ornamentation is the result of an exothecal growth, which we have found to be very limited in variety. The costa is the only form bearing any direct relation to any of the other parts of the coral, and therefore the only one of importance.

The costae have considerable value because they are usually of the same number or multiples of the same number as the septa. This reveals partially the internal structure of the coral though oft times the costae are so rudimentary and worn as to leave one in doubt as to their original form or number. Ornamentation, nevertheless, bears a resemblance in the same species and in well preserved specimens it is frequently an aid in determination of species.

4th.- The Appearance of the Actinal Surface.

A great deal may be noted by observing the Actinal end of the Corallum; the solidity of the sclerenchyma, the septa whether distinct or not, the depth of the calyx, the character of the columella when present, or the nature of the fossula if developed, all of which have value in classification.

The solidity of the sclerenchyma is an ordinal characteristic. It is also upon this feature that the sub-orders of the Zoantharia are based. Actinaria has no sclerenchyma. Antipatharia has a sclerenchyma so loosely constructed as to be of no value in determining its species. In Madreporaria the sclerenchyma is well developed. The sub-order Madreporaria, is divided into sections largely on the basis of the structure of the sclerenchyma. M.perforata is more or less conspicuously porous, while M.Rugosa and M. Aporosa are principally solid and compact.

The septa,perhaps have the greatest value in classification. They bear the most intimate relation to the living polyp, and to that part of the polyp upon which the classification into orders is based. These orders are:

I. Alcyonaria.- "Polyps with eight mesenteries and eight broad pinnately fringed tentacles placed in a single row around the mouth" (Zittel);

II. Zoantharia.- "Polyps with twelve or more simple tentacles, usually arranged in more than one circle about the mouth, and usually in multiples of six or four". (Zittel)

As mentioned before, the tentacles and mesenteries of the living calcareous-secreting polyp correspond in numbers to the septa of the corallum; by knowing the number in the one case that of the other may be determined.

Further than this, the number and arrangement of the septa are used by some (Zittel) to divide Madreporaria into its two groups,

I. Tetra-coralla, and

II. Hexa-coralla.

In the classification of these groups the symmetry of the individual is usually considered, as is also the arrangement of the secondary septa along one or more primary septa.

The thickness of the septa, and the extent of the development from the theca toward the center, or from the base toward the upper end also serve in the determination of genera and of species. Sometimes a characteristic margin of the septa, wavy or spiny, determinees the species.

Where no septa are present we must look elsewhere for classificatory values, unless we form a group as classified without septa, in contrast with those having septa.

The depth of the calyx may have value only in the species Sometimes it becomes a conspicuous characteristic (Zaphreutis cornicula, Pl. VIII, Fig. 2), and at times the calyx is wanting (Hadrophyllum orbignyi, Pl. XII. Fig. 1).

Summing up the external features of the coral, we may say that the septa, combined with the general structure of the sclerenchyma, constitutes the most important values in the gerenal classification, and the modifications of these furnish a partial basis for family, generic and specific characters.

# INTERNAL VALUES.

For an accurate determination of the internal structure of the coral it seems necessary to make careful sections of the same. A vertical section through the center of the coral will show the arrangement and extent of the tabulae; the columella, when present; the development and nature of dissepimental tissue; and the thecal structure. See Plates XXII to XXXV.

A transverse section will show the number and arrangement of the septa, when present; the extent of development toward the center; outer and inner zones, if distinct; dissepimental tissue; and thecal structure. See Plates XXII to XXXV.

In fact, two such sections show all the characteristics to be found in the coral, and this is the true way to determine the real structure of calcareous remains.

The internal values are doubtless the true values for classification. Here we find, if it may be found at all, the occurrence and number of the septa, the importance of which has already been mentioned. The degree of development of the septa in the coral can be determined accurately only by section. In many cases certain septa are more or less strongly developed or reach nearer the center than in others; this gives rise to an important basis for classification of families, tribes and genera. We may also note that the abnormal development of one or more of the septa, or the rudimentary development of one or more, aids greatly in the characterization of the genera of some of the group Tetracoralla of the Madreporarians. The Columella has considerable value in the tribe Petraniae of the family Inexpleta, but is usually absent in other forms.

The pali when developed ought to be strong in value in divisions of tribes or genera, though they are very limited in their development.

The general condition of the interseptal spaces, whether vacant or more or less filled by modifications of the septa and tabulae, are also of prime importance in the characterization of families, tribes and genera, and to a less degree of species.

Zittel divides the group Tetra-coralla into two families on the basis of the absence or presence of tabulae and cellular interseptal tissue. Nicholson divides the same group into three main sections on a slightly different basis. His sections are:

I. Cyathophylloidea (Pl.XXII, Fig. 4 and 5; and Pl.XXIII, Fig. 3 and 4 ), constituting those Rugose corals having the peripheral region of the visceral chambers more or less extensively occupied by vesicular dissepimental tissue;

II. Zaphrentoidea (Pl. XXV, Fig. 3 ), including "those Rugosa in which there is a comparatively limited amount of dissepimental endotheca and having a proportionately extensive development of tabulae";

III. Cystiphylloidea (Pl. XXIX, Fig. 1 and 3), embracing "those

Rugose corals in which dissepimental tissue is, in general, extensively developed, while tabulae are absent or are incompletely developed and septa more or less imperfect".

The value of the condition of the interseptal spaces or, the inter-relation of septa, dissepiments and tabulae is apparent especially in the group Rugosa, where dissepimental tissue reaches the height of its development.

Dissepimental tissue is generally developed regularly and assures considerable safety in the classification of species.

The synapticular developments are quite numerous in some species, but are of considerably less value than dissepimental tissue.

The tabulae are of equal rank with the septa, in classification. Where the one is absent the other usually serves as its supplement. In Madreporaria perforata (Nicholson) the septa are usually rudimentary or absent, but the tabulae are commonly developed and serve as the basis for classification.

The regularity, form and extent of development furnish ample means for the lower divisions in classification.

The porosity of the sclerenchyma has been mentioned before. This is an important feature in the group Hexacoralla. The number and arrangement of the mural pores, forms the basis for family divisions and characterizes genera and species. The families Poritidae, Madreporidae, Eupsamidae, Fungidae and others, are strongly marked by their mural connections by way of these pores.

Stereoplasmic developments as having value, have not been mentioned, though it is usually considered a secondary secretion, yet it serves to characterize certain divisions of corals, among which is the family Cyathophyllidae of the group Rugosa.

Summing up the internal values in classification as compared with those mentioned under external values, we find the general structure of the sclerenchyma as being foremost, followed by the septa and tabulae, then the dissepimental tissue. Next to these may be mentioned mural pores, synapticulae, stereoplasm and columella.

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# MODERN CLASSIFICATION OF CORALS.

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The present system of classification of corals falls far short of being definite and comprehensive. The class Actinozoa is divided into two groups on the basis of the number of mesenteries and tentacles, neither of which remain in the coral, but may usually be known from the number of septa. Alcyonaria is further divided into families on the basis of sedentary or free-living and the consistency and form of the axial skeleton.

Zoantharia is separated by Nicholson into three sub-orders, according to the consistency of skeletal formation, Madreporaria being the only sub-order having a recognizable corallum. This is further divided into four sections,

I. M.Aporosa,
II. M.Rugosa,
III. M. Fungida and
IV. M. Perforata.

There seems to be no clear cut distinction between these sections. The sclerenchyma is spoken of under Aporosa and Rugosa, as being "compact and solid". No mention is made of it under Fungida, while under Perforata it is "more or less conspicuously porous or reticulate". From this we know no distinction between Aporosa and Rugosa, and nothing of Fungida. The theca in Aporosa and Rugosa is "complete and imperforate", with no mention of its condition in the other sections. The septa under both Aporosa and Rugosa are "well developed and usually lamellar, with smooth or dentate edges". In Rugosa they are "alternately long and short", but in Aporosa no mention is made of their arrangement. Under Fungida the "septa are usually solid and lamellar, occasionally perforated". Under Perforata they are "more or less porous".

This shows an indefiniteness in regard to the septa throughout all the sections, and no clear distinction between any of them. The same uncertainty may be noted in regard to the dissepimental tissue. Under Aporosa it is "more or less l rgely developed", under Rugosa, "largely developed", under Fungida "may or may not be developed", and under Perforata "usually present". Of the tabulae, Aporosa has them "present sometimes. Rugosa, "often well marked"; Perforata, "commonly developed", without any mention under Fungida. Thus we see the indefiniteness in our modern classification.

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# DESCRIPTIONS

## WHICH ARE GIVEN FOR CORALS ARE OFTEN INSUFFICIENT FOR THE IDENTIFICATION OF SPECIES.

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With a defective basis for classification, it becomes highly important that generic and specific descriptions of specimens should be accurate and "clear-cut". These descriptions are faulty and in many cases insufficient for a satisfactory identification of the species. This I shall attempt to show in the following.

When one undertakes to study the structure of some of the more common species of fossil corals, many things are found to be provokingly different from the recorded descriptions of these species. For this reason I have undertaken a study of both the internal and external structure of a number of these forms, with a view to ascertaining whether the methods used in the classification of this group are justifiable, and whether the descriptions given are sufficient for the identification of species.

I obtained a number of specimens, including seventeen genera and thirty four species, from S. A. Miller of Cincinnati, Ohio. They were all carefully determined and labelled by him, hence the determinations were presumably correct. The specimens agreed fairly well with the descriptions given by Nicholson, Zittel, Rominger, Hall and others, so long as attention was confined to external characters, but a more detailed examination of the internal structure of the specimens revealed many curious discrepancies. We shall undertake to show some of these inconsistencies, which we think will prove that descriptions of fossil corals based on external characters alone, are often unreliable. This may be done most expediently by quoting the authority and his descriptions of the species, with a comparison of the specimen as given by Miller.

I have arranged the genera in alphabetical order.

AMPLEXUS YANDELLI. Milne-Edwards.

Described by C. Rominger, Michigan Survey, Vol. III,- "Conico-cylindrical flexuose stems, annulated by five wrinkles of growth with intermediate coarse rugae, and frequently of a jointed structure through periodical constrictions of the calyces, and continued growth of the stem without interruption of the continuity of the epithecal wall. Calyces deep, with erect margins, surrounded by about sixty alternately large and small vertical crests. The bottom of the calyces is formed by flat or warped diaphragms, depressed on one side by a deep septal fovea. The lamellae are restricted to the outer circumference of the diaphragms,but sometimes they extend to the center as superficial ridges."

Plate XI, Fig. 1, represents a view of a group of Z. Yandelli. Nos. I, 2 and 3 are from the University Museum. Nos. 4, 5, 6 and 7, from Miller. Though no slides were obtainable, yet by careful observation, the following inconsistencies were noticeable. Specimens No. 1, 2, and 3 clearly show fossulae. No. 4 showed none, Nos. 5, 6 and 7 showed a very poorly developed one. Nos. 5, 6, and 7 are cylindrical, the others are more or less uniformly conical and curved. No. 3 showed no dissepimental tissue and the tabulae poorly developed, while in Nos. 4, 5, 6 and 7 the tabulae and dissepiments were well developed. No. 4 has the alternate septa shorter, with inner edges free, while Nos. 5, 6 and 7 have septa uniform in length with the inner edges united to form an inner wall.

CYATHOPHYLLUM HOUGHTONI, Rominger.

Described by Rominger in Michigan Survey, Vol. III, "Erect, conico-cylindrical polyp cells. Surface obtusely wrinkled, rarely interrupted by acute annulation, Calyx deep. Lamellae alternately larger and smaller, linear near the bottom of the calyces, roof-shaped on the ascending walls and frequently explanate into a blistered, plicated membrane near the margins. The surface and the edges of the lamellae within the calyces are covered with granulations and by short interrupted, transverse carinations or rugosites.

There are no small, vesiculose, interstices between the radical crests, as in the outer area of other Cyathophylla. The lamellae themselves open in two diverging leaves, which join in the interstices into a continuous calycinal membrane of a blistered structure. The calycinal surface represents a complete laminar bag folded into plications, with the acute edges of the folds directed inward, and the rounded curve turned outward. The coral is formed by invagination of a series of such bags, which have elongated, blister-like intervals between them, but are in intimate connection by the edges of their crested plications, which correspond to each other and combine into vertical laminar dissepiments extending through the whole length of the corallum. The central area is septate by transverse diaphragmatic plates of much regularity. The vertical lamellae intersect them as continuous leaves nearly to the center."

Pl. IV. Fig. 1, represents our original specimens. Pl. XXII, Fig. 1, shows transverse sections just beneath the calyx, Fig. 2, vertical section from base upward to where the transverse section was taken, Fig. 3, tangential section.

Our specimen agrees very well with the above description, except that the surface and edges of the lamellae within the calyces do not show any granulations or carinations. Also, that the diaphragmatic plates are not formed with any marked regularity, but are confined principally to the interceptal spaces, rather than being continuous throughout the viscerl cavity.

CYATHOPHYLLUM DAVIDSONI.

Synon., Acervularia davidsoni, Milne-Edwards.

Described by Rominger in Michigan Survey, Vol.III, "Growth in large, convex masses, or in lenticular, discoid expansions. Growth usually aştraeiform, with intimately connected polygonal calyces surrounded by acute linear crested edges. Lamellae long and short, in alternation, but equal in size near the calyz margins, crenulated ate the edges and decorated by arched carinae crossing their flanks; from thirty-six to forty lamellae in the circumference of a calyx. Interlamellar interstices filled with delicate, transverse, vesiculose plates. The central area is distinctly septate by diaphraghms, which are not much intersected by vertical crests on the circumference of the central area, in polished, transverse sections, a more compact ring is visible, formed by a thickening of the longer lamellae, and by the abrupt termination of the alternating shorter ones within this circle, but not a trace of an actual inner wall is developed".

Pl. IV, Fig. 2, shows rough specimens;

Pl.XXII, Fig. 4; transverse section through several corallites, Fig. 5, vertical section through the center of two corallites; (a), represents the diameter of the central area; (b), (below) includes the diameter of one corallite; (c) is the wall.

By carefully examining the section Pl.XXII, we find this disagreement; the central area is <u>not</u> distinctly septate by diaphragms. Minute cross plates between the septa are evident but they are not tabulae, properly speaking, they are not even connected through the septa, as is noticeable in the illustration. The lower right hand specimen in Fig. 2 of Pl.IV, shows conclusively diaphragms well developed and for that reason is a different species from the upper specimen in the same Fig. from which the section referred to were made. Miller's generic description implies the cells as having two separate walls. Rominger by describing a polished transverse section avoids this error and observes the thickening of the lamellae in the region of the inner margin of the shorter ones. A detailed account of the structure of the dissepimental tissue here would suffice for the identification of this species, it being very uniform in its development.

CYATHOPHYLLUM RUGOSUM, Milne-Edwards, Synon, Aatraea rugosa, Hall.

Described by Rominger in Michigan Survey, Vol. III, "Astraeiform colonies of polygonal, intimately united stems, which in some specimens of a certain state of preservation are separable, and present longitudinally ribbed polygonal stems, annulated by transverse wrinkles of growth. Inter-lamellar interstices transversed by small vescicles filling them to the margins of the calyces. The center of the stems is transversely septate by diaphragms, intersected in their outer circumference by continuous vertical lamellae; certainly their continuity is interrupted and the ends are merely carinations on the upper face of the diaphragms".

This is illustrated in Pl. V, fig. 1,- sections Pl.XXII Fig. 1 and 2. The general description of external features agree perfectly; that of the small vesicles filling the interlamellar spaces does not show well in the sections. The sections certainly are poor here, but they serve to show that dissepimental tissue is poorly developed and that it is more or less irregular or indefinite in formation. The diaphragms also are indistinct if at all present.

CYATHOPHYLLUM PANICUM, Winchell.

Synon., Diphyphyllum panicum, Rominger.

Described by Rominger, Michigan Survey, Vol. III, "large colonies of diverging, partially contiguous cylindrical stems, multiplying by prolific calcinal gemmation. Stems longitudinally striate and transversely wrinkled by lines of growth. Calyces deep, bottom of which occupying about one-third of the diameter of the stems, formed of vesiculose compound diaphragms, which are only in their peripheral circumference intersected by vertical lamellae. Peripheral area filled with small interlamellar vesicles; the two areas are not defined from each other by an intervening wall".

Slide. Pl. XXIV, Fig. 3, shows transverse sections; Fig. 4, vertical section, shows tabulae and dissepiments.

The description just quoted agrees satisfactorily with our specimen, but we see how the description could have been improved by noting the peripheral edges of the diaphragms as they are usually turned upward; also by noting the general form and arrangement of the dissepiments, and that the larger ones are next to the outer wall, those farther in, being smaller and regularly arranged. A certain amount of stereoplasm is also evident in the peripheral development of the section. Fig. 3.

CYSTIPHYLLUM AMERICANUM, Milne-Edwards.

Described by Rominger, Michigan Survey, Vol. III, "Single polyparia, surrounded by a perfect, concentrically wrinkled epithecal wall, of conical, or,in the progress of growth, of horn-shaped, curved, or straight cylindrical form. Calyces moderately deep, with explanate margins, equally tapering toward the bottom, which is generally occupied by a few irregular blisters. The ascending calyx walls are sometimes only slightly blistered, and folded into stout radial rugae. In other specimens the rugae are obsolete and the blisters principally obvious".

Pl. XIII, Fig. 2, group of C. americanum. No. 1, 1, 1, showing different parts of a single broken specimen, and No.3, are from Miller; Nos. 2 and 4, from University Museum. Three of the specimens have been worked into slides. No. 1 may be seen in a vertical section in Pl. XXVIII, Fig. 1. No. 2 in Pl. XXIX, Figs. 1,3; No. 3 in Pl.XXVII, Fig. 2, and XXVIII, Fig. 2.

These were all given me as the same species and agree very well, in external appearances, so far as the description given above goes. The study of great differences in internal structure of these specimens becomes of considerable interest when we remember that Miller and other authorities have classified them all as C. americanum.

No. 1, 1, 1, shows some what the inner structure,but the same specimen is shown in section Pl. XXVIII, Fig. 1, showing tabular formations in the central area, and the vesicular structure along the outer area; this specimen has well developed septa and hence cannot belong to the genus Cystiphyllum.

Pl. XIII, Fig. 2, No. 2 is shown in section in Pl.XXIX Fig. 1 and 3. Here we find no traces of septa or tabulae. All is made up of blister-like vesicular tissue, the outer vesicles being smaller than those about the center; the development has taken place from without inward.

Pl. XIII, Fig. 2, No. 3, is shown in section in Pl.XXVII Fig. 2, and Pl. XXVIII., Fig. 2. Here are well developed septa alternately shorter and longer, the shorter being very short and the long ones reaching to the central area. Tabulae are numerous and well developed, filling the central area of the corallite. The outer zone is filled with rather coarse and irregular vesicles. The range of characteristics in the above specimens is certainly too wide to be admitted into the same species, whereas, had a definite description of the internal structure been made a more definite location of the specimen might follow.

EMMONSIA HEMISPHERICA, Milne-Edwards.

Synon., Favosites hemispherics, Yandell and Shumard Zoir Tabulate Corals.- "Corallum general hemispherical or irregularly spherical in shape, massive, often several inches in diameter. Corallites prismatic, often with rounded angles thick walled. Calices subpolygonal, irregular in size and form, with thick margins. Septa in the form of longer or shorter spines, but often not recognizable. Tabulae generally in the form of thin, flexuous, close-set laminae, which for the most part only extend across but a third or a half of the total diameter of the tube. At other times the tabulae are complete and they are occasionally quite regular and horizontal. Mural pores usually biserial, very closely set, opposite or alternating".

Pl. XVIII, Fig. 1, shows a group of rough specimens; Pl. XXXIII, Fig. 1, a vertical section; and Fig. 2, a transverse section.

The above description gives a broad range as to the septal development. In our specimens no spines are recognizable. The tabulae also are comparatively thick, not close-set,and extend distinctly across the diameter of the tube (Pl.XXXIII, Fig. 1). The mural pores also are not closely set.

There should be a better agreement than this and for this reason I am led to believe that my specimen belongs to some other species.

FAVOSITES FORBESI, VAR. OCCIDENTALIS, Hall.

Synon. F. forbesi, var. Waldronensis, Nicholson.

Described by Nicholson in Palaeozoic Tabulate Corals, "Corallum forming globular or pyriform masses varying from half an inch to two inches or more in diameter, and attached by a broad peduncle, the lower part of which may be covered by an epitheca. Large corallites, varying from one and a half to two lines in diameter, and proportionately very numerous, the small corallites occupying the angular spaces between the former, and varying from a fiftieth of an inch to more than half a line in diameter. Septa apparently obsolete. Tabulae numerous, thin, horizontal, usually about seven in the space of the two lines".

This species is illustrated in Pl. XV. Fig. 2 in the rough; Pl. XXXI, Figs. 1 and 2.

The above description seems insufficient, from the fact that no reference is made to the mural pores (P) which are certainly present and numerous and apparently in two or three rows on each prismatic face of the corallite. The inner faces are also marked by rows of minute spines (sp Fig.1 and 2), which serve to characterize the species.

FAVOSITES GOLDFUSSI, Milne-Edwards and Haine.

Synon., F. gothlandica, Lamarck.

Described by Nicholson in Palaeozoic Tabulate Corals, "Corallum composite, forming discoidal, spheroidal, turbunate,or hemispherical masses of irregular shape and size. Corallites prismatic, calices regularly polygonal, with thin walls, generally tolerably uniform in size in any given specimen, but always having smaller and younger ones intercalated among those of average size. Walls of the corallites not thickened toward their mouths, and furnished with two (sometimes one or three) rows of mural pores on each prismatic face. Pores alternately placed surrounded by an elevated margin Tabulae complete, rarely inosculating; sometimes incomplete and inosculating; sometimes incomplete and inosculating in parts of the colony, while complete in others. Septa usually obsolete or irrecognizable, sometimes represented by rows of tubercles or even by well developed radiating spines".

Illustrated, Pl. XVI. Fig. 1. Sections Pl. XXXI,Fig. 3, 4, and 5.

The agreement of our specimens with the above description seems entirely satisfactory, and on account of the variations to which this species is subject (Nich.) by way of mural pores, tabulae and setal remnants, a definite specific character based on any of these seems impossible. Our specimens, however, appear very uniform in this respect and readily distinguishable.

FAVOSITES HAMILTONIAE, Hall.

In the references at hand no specific description of this species could be found.

The internal structure of this species (see Pl.XVII, Fig. 1) is shown in pl.XXXI, Fig. 6; Pl.XXXII, Fig. 1.

The general shape of the corallites, their walls, mural pores, and spinules, are clearly shown in the sections. All of these essential characteristics are more or less indeterminable,except by microscopic sections, which in all cases afford a ready means for a specific description.

This statement applies with equal force to F.magarensis Hall. which is figured in Pl. XXXII, Fig. 2 and 3.

HALYSITES CATENULATA, Linn.

Rominger in Michigan Survey, Vol.III, page 78, describes in general the limit of a variety of forms of the chain coral and desists from making a distinction and applies the specific name,H. catenulata, to all forms. This, it seems to me, shows a weakness in his classification, the limit he gives to the species being too great. On the other hand, Nicholson, in his Palaeozoic Tabulate Corals, page 228, takes the more scientific and proper method by describing the thin, transverse section of a typical H.catenulata, Linn. The following is Nicholson's description;- "In these cases the epitheca and proper walls of the corallites are directly continuous (as in H. escharoides), but there is now the additional feature that between each pair of the normal corallites there is intercalated a much smaller sub-quadrate tube which forms the medium of union between the former. This interstitial tube, moreover, does not seem to be bounded laterally by an inward prolongation of the walls of the large tubes (as one would expect it to be) but it appears to be enclosed by a proper and peculiar wall of its own on the two sides where the large tubes on either side come against it; and this proper wall is at once distinguished under the microscope from the wall of the large tubes, by its much darker colour and seemingly different texture".

This illustrates clearly the value of microscopic sections as an essential aid in classification. Our illustrations are found in Pl. XX, Fig. 2, sections, Pl. XXXIV, Fig.3 and 4. The specimen, though in a classified condition and difficult to grind, shows the structure with considerable clearness.

HELIOLITES INTERSTINCTUS, Linn.

Described by Rominger, Michigan Survey, Vol. III, "Visceral tubes from one to one and a half millimeters in width. Vertical crests quite prominent, almost reaching the center, and composed of rows of spinules pointing obliquely upward with their apices. Coenchyma composed of minute, polygonal, transversely septate tubules. Interstitial spaces between the larger tubes usually much exceeding one tube diameter. Diaphragms rarely flat, and simple, generally complicated into a cellular network with the spinulose, vertical crests, with a nodular projection in the center, formed by the converging apices of the spinules. No central columella. In vertical sections the channels of the larger tubes are scarcely distinguishable from the surrounding septate coenchyma, because the intersection of the spinules with the diaphragms divides the interiors of the larger tubes into small cell spaces, similar to the surrounding coenenchym tissue. The mode of growth is in discoid, subplane expansions, with a concentrically wrinkled epithecal crust on the lower side".

Our illustrations are shown in Pl.XIX. Fig. 2, Pl.XX; Fig. 1, sections XXXIV, Fig. 1 and 2.

The specimen at hand hardly agrees in every respect with the above description, agreeing better with that of H.pyriformis, Hall, in which the "tubes are about one millimeter wide, radiated by twelve spinulose, vertical crests. Diaphragms flat, simple, or anchylosed, with the spinulose, vertical crests into an irregularly cellulose mass, filling the tube cavities. Coenchyma of minutely tabular structure divided by transverse septa".

The description being based principally on the internal structure can scarcely be improved on by means of the slide, and yet it seems very necessary to render a portion of the specimen into a slide for proper determination.

LITHOSTROTION PROLIFERUM, Hall.

Synon., L. Mamillare, Edwards and Haine.

Miller gives L. canadense, Castelnau as synon. with mamillare. This would bring L. proliferum, L.Mamillare, and L. canadense as synonymous.

L. proliferum, is described by Rominger in Michigan Survey as follows;- "Large corallites of remote cylindrical stems, from one to two centimeters in diameter, multiplying by gemmation from the margins of the calycinal disks, or astraeiform masses of intimately united, polygonal stems of similarly variable sizes, and unequal in the same specimens through the intermixtures of frequent young cells. Bottom of cups reflected into a large, conical protuberance , carinated on the sides by the converging ends of the radial lamellae, and terminating with a laterally compressed cristiform edge".

See Pl. VII, Fig. 2, for L.proliferum; and
Pl. VI, Fig. 2, for L. canadense.

Both of these specimens agree with the description so far as I am able to determine by comparison. Unfortunately the specimens were either so exceedingly hard or firable that a section could not be obtained in my limited time for work. Nevertheless, we still remian in doubt, even though our specimens are in a good state of preservation, as to the exact specific name or as to the identity of the two specimens. How can we tell as to the bottom of the cups when our specimen has no cups? Pl. VI, Fig. 2, shows the structure of the cups nicely, but the principal specimen, Pl. VII, Fig. 1, shows nothing about the cups. Here we may notice again the valve of internal structure for classification. A classification is all the more valuable if but a section is needed for its identification, rather than an entire corallum, and the only way that such a classification could be accomplished is evidently by means of a definite knowledge of its internal structure.

STREPTELASMA CORNICULUM, Hall.

Decsribed by Rominger, Michigan Survey, Vol. III, "Elongate conical, symetrically curved, horn-shaped corals; middle sized specimens have a diameter of about three at the calyx margin by a length of from seven to eight centimeters. Calyces moderately deep, with erect acute margins, steeply inclined side walls, and a variably formed bottom. Lamellae linear, stout; alternately larger and smaller, from 120 to 130 in the circumference of calyces, three centimers wide. The radial crests become labyrinthically entangled in the center of the cells, and usually for a broad convex protuberance A small septa fovea is always present. The center of the polyparia is found to be intersected by well-developed transverse diaphragms."

Our specimens are represented on Pl. XII, Fig. 2, and in sections on Pl. XXVII, Fig. 1 and 2.

Of this species, we notice a similar weakness in the description of internal structure without which one is more or less uncertain as to the proper location of his specimen. The stereoplasmic developments forming an important characteristic is not mentioned The development, usually in pairs, of the septa; the prominence of two opposing ones; and the uniformity of their thickness has not been noticed; all of which would aid in recognition of the species. The transverse diaphragms- if they may be so called, are weak and very irregular.

SYRINGOPORA MACLURII, Billings.

Described by Rominger, Michigan Survey, Vol. III. "Tubes about three millimeters wide, flexuose, occasionally touching each other, and then diverging again, or at other times of more regular, subparallel growth, with interstitial intervals usually larger than a tube diameter, and with remote, slender, transverse tubules of connection. This coral resembles S. perelegans, Billings differing from it only in having a larger tube size, and a more irregular mode of growth, but in many instances it becomes difficult to decide whether a specimen belongs to one of the other forms"

Pl. XVIII, Fig. 2, shows specimen in the rough Pl XXXII Fig. 6, shows section of same through two corallites. This section is comparatively poor, yet it serves to show, that there is sufficient internal material to aid greatly in describing and classifying this species, and in determining more definitely the distinction between this and other species.

SYRINGOPORA TABULATA, Milne-Edwards.

Described by Rominger, Michigan Survey, Vol.III, "Tubules about one millimeter wide, closely approximated, with intervals narrower than a tube diameter; the transverse connecting tubules branch off in sub-regular, verticillate position, and correspond in all tubes in certain levels, by the lateral anchylosis of which almost uninterrupted lamilar floors are formed; this is, however, not an invariable structure. The tubules are distinctly radiated by twelve spinulose crests, and on the surface of the tubules a dull, longitudinal striation is usually noticed. Diaphragms funnel-shaped, with tubular invaginated ends".

Pl. XIX, Fig. 1, shows S. tabulata in the rough state.

Pl. XXXIII, Fig. 3, transverse section, Fig. 4, vertical section.

The infundibular arrangement of the tabula is very well marked in our specimen and furnishes an excellent means, in addition to the general external forms, for specific characterization.

The anchylosis of the tubes into laminar floors is also very nicely shown in the sectional form.

TETRADIUM FIBRATUM, Safford.

Our specimen, Pl. XXI, Fig. 1, with sections, Pl. XXXV, Fig. 1 and 2, is not in a very good condition for study. Parts of the fossil were in a state of decay, or in a silicified state with internal structures more or less obliterated. The generic characters of Tetradium, Dana, demand "numerous complete tabulae", Miller. No traces of tabulae are noticeable, Pl. XXXV, Fig. 4. Whether this species has none, or whether they have been obliterated, I am unable to say. But this is evident, if any traces of tabulae exist at all the only sure way of determining their presence is by means of microscopic sections.

STROMBODES PENTAGONUS, Goldfuss.

Synon. Strombodes striatus, D'Orbigny.

Described by Rominger, Michigan Survey, Vol. III, "Large discoid expansions covered on the lower side with a concentrically wrinkled epitheca, and attached at the central apex. Surface of disks composed of irregularly polygonal, shallow calyces with an abrupt central depression. Diameter of calyces very variable in different specimens. The steep walls of the inner cell pit are surrounded by about thirty stout, crest-like plications, which, reduced to a smaller number by coalescence, unite in the center, and form there a styliform protuberance. On the expanded marginal portion of the calyces the plications lose their crest form and are reduced to rounded rugae which multiply to three or four times their original number. In some specimens the inner cell pits are surrounded by a monticulosed raised rim; in others the surface of the calyces is roughened by blisters without a distinct radial striations".

Pl. VII, Fig. 2, represents a few calyces. Pl. XXV, Fig. 1, transverse section, Fig. 2, vertical section through the center of the corallite.

The above description sets forth very clearly the external characteristics of this species, which, after all is scarcely sufficient to distinguish between the several species under the genera, Strombodes.

We can scarcely see, from the section Pl. XXV, Fig. 1 and 2, the clearly defined internal structure. With such material readily available for the description of species, is it not unscientific to neglect the use of such material as an aid in classification?

ZAPHRENTIS GIGANTEA, Lesueur.

Described by Rominger, Michigan Survey, Vol. III, "Conico-cylindrical, horn-shaped polyparia, attaining in some specimens a size of two and a half feet in length, by a diameter of three inches. Some enlarge their diameter rapidly to a certain thickness, and then grow on in a uniformly cylindrical shape; others are in the young state, slender, flexuose, and irregularly constructed stems, and grow gradually to larger diameters. The surface of the polyparia is covered by an epitheca with shallow annular wrinkles of growth, and longitudinally ribbed by septal striae, which, however, are not in all specimens equally distinct. Calyces spacious, with erect walls, and acute, wedge-like margins; bottom broad, marginally depressed and flat in the center. In one place of the circumference the diaphragms are more deeply depressed by a septal fovea. Radial lamellae stout, linear, alternately long and short, but appearing nearly equal on the margins of the calyces, where the sharp crested leaves of the inside expand into low rounded rugae.

The number of lamellae in calyces of about two and a half inches diameter is 150 to 160, half of which are of the smaller size."

Specimens are shown Pl. VIII, Fig. 1; sections Pl.XXV, Fig. 3 and 4, and Pl.XXVI, Fig. 1.

Here again we find two specimens whose internal structure shows a marked difference. Pl.XXV. Fig. 3, shows strongly developed septa alternately long and short, the shorter ones being rudimentary. The interseptal tissue is scarcely present. Pl.XXV, Fig.4, being but a section of the original specimen, is sufficient to show thelamellar structure of the septa, the primary ones reaching the center, the shorter ones extending about one-third the way to the center. Abundant dissepimental tissue is evident and a stereoplasmic development is well shown. Fig. 3 shows 52 septa, while Fig. 4 contains at least 200.

The above noted differences seem too important to admit the two specimens to the same species. The internal structure of the same specimen, as Fig. 4, may be further noticed in Pl.XXVI, Fig. 1. In this, dissepimental tissue is highly developed; the tabular formations are weak and very irregular, affording abundant material for internal characterization, had a description of it been given.

The result of our investigations as set forth in detail in this thesis, seem to warrant the following general conclusions:

1st.- That the present system of classification,based largely on external characteristics, is indefinite, unreliable,and unscientific.

2nd.- That the available means to a more definite classification have not been utilized.

3rd.- That an investigation and description of the internal structure of fossil remains furnishes an essential aid to classification.

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## EXPLANATION OF PLATES.

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### PLATE I.

Fig. 1. The external appearance of a living typical Actinozoan; (after Loomis, "Synopsis der drei Naturreiche".).
- a, Mouth
- b, Oral disc;
- c, Pentacles;
- d, Outer margin of the oral disc;
- e, Body wall of the coral;
- f, Basal plate or foot plate.

Fig. 2. A longitudinal medial section showing the internal structure of the living polyp. (After Loomis).
- a, Tentacle;
- b, Mouth;
- c, Oesophageal tube;
- d, Inner opening of oesophagus;
- e, A mesentery;
- e, A narrower mesentery which does not reach to the oesophagus;
- f, and g, Mesenterial openings;
- i, Genital organs;
- i, The gastrovascular cavity.

### PLATE II.

Fig. 1. Diagrams showing transverse sections through the polyp,
A, in the region of the oesophagus;
B, just beneath the oesophagus.
- a, Body wall;
- b, Wall of the oesophagus;
- c, Mesenteries;
- d, Interseptal chambers of the gastrovascular cavity;
- e, Inner cavity of the oesophagus;
- f, Center of the gastro vascular cavity.

Fig. 2. Vertical section of a polyp of Astroides calycularis. A recent Zoantharian.
- t, Tentacles;
- g, Oesophagus;
- w, Body wall;
- Me, Flat face of a mesentery;
- f, Edge of a mesentery;
- sp, One of the calcareous "septa" of the corallum, intervening between the mesenteries;
- r, Reproductive organ;
- Ca, Corallum;
- Co, Columella;

Coe, Coenosarc. (After Lacaze-Duthiers.)

Fig. 3. Diagram of a cross section of Caryophyllia, the soft parts being unshaded and the corallum black.
oe, Oesophagus with the "directive mesenteries" (m) at each end.
w, Body-wall.
s, Septum.
t, Theca. (Slightly altered from von.Koch)

PLATE III.

Fig. 1. A branch of the recent Dendrophyllia nugrescens,showing lateral gemmation.
a, A corallite;
c, Goenchyma.
Fig. 2, Transverse and vertical section of Favosites, enlarged showing intermural budding.
co, A young corallite.
Fig. 3, Section of Chaetetes septosus, enlarged to show fission of the corallites.
A, Cross section of a few corallites , some of which show the commencing fission of a tube by the development of an internal longitudinal partition (p).
B. Vertical section, showing a single corallite (c) splitting into two.

PLATE IV.

Fig. 1. Lateral and calicular view of Cyathophyllum houghtoni.
Fig. 2. Cyathophyllum davidsoni.

PLATE V.

Fig. 1. A group of Cyathophyllum rugosum;
Fig. 2. Given as Strombodes pentagonus, showing various views.

PLATE VI.

Fig. 1. Diphyllum strictum;
Fig. 2. Lithostrotion canadense, showing upper and lower view.

PLATE VII.

Fig. 1. Lithostrotion proliferum;
Fig. 2. Strombodes pentagonis.

PLATE VIII.

Fig. 1. Zaphrentis gigantea.
Fig. 2. Zaphrentis cornicula.

PLATE IX.

Fig. 1. Zaphrentis dalei;
Fig. 2. Zaphrentis prolifica.

PLATE X.

Fig. 1. Zaphrentis spinulosa;
Fig. 2. Zaphrentis calceola.

PLATE XI.

Fig. 1. Group of Amplexus Yandelli; Nos. 1, 2 and 3 from Museum of U. of I.
Fig. 2. Lophophyllum proliferum.

PLATE XII.

Fig. 1. Hadrophyllum orbignyi;
Fig. 2. Streptelasma corniculum, showing end and side views; The one at the left shows polished surface.

PLATE XIII.

Fig. 1. Cystiphyllum vesiculosum, side and end views;
Fig. 2. Cystiphyllum americanum;
1, 1, 1, The different parts of a single broken specimen.
2 and 4. Specimens from Museum, U. of I.

PLATE XIV.

Fig.1. Protarea vetusta;
Fig. 2. Calapoecia cribriformis.

PLATE XV.

Fig. 1. Calapoecia cribriformis; (This had been given by Miller as Favistella stellata.).
Fig. 2. Favosites forbesi. Var. occidentalis.

XVI.

Fig. 1. Favosites goldfussi, No. 2 having smaller corallites than No. 1 and being somewhat decomposed.
Fig. 2. Favosites polymorphus. Specimens much decomposed.

PLATE XVII.

Fig. 1. Favosites hamiltoniae;
Fig. 2. Favosites niagarensis (large corallites). The figure at the right shows a broken section.

XVIII.

Fig. 1. Emmonsia hemispherica;
Fig. 2. Syringopora maclurii.

PLATE XIX.

Fig. 1. Syringopora tabulata;
Fig. 2. Heliolites interstinctus, lime formation.

PLATE XX.

Fig. 1. Heliolites interstinctus, in flinty state.
Fig. 2. Halysites catenulatus.

XXI.

Fig. 3. Tetradium fibratum. ,
No. 1 is from Museum, U. of I., and has smaller corallites than 2 and 3.
Nos. 2 and 3 are somewhat decomposed.

## INTERNAL STRUCTURE OF CORALS.

### PLATE XXII.

Fig. 1. Transverse section of Cyathophyllum houghtoni, just beneath the calyx.
Fig. 2. Vertical section of same specimen from base upward to where transverse section was taken.
Fig. 3. Tangential section of same.
Fig. 4. Transverse section of Cyathophyllum davidsoni, showing several corallites.
Fig. 5. Vertical section through the center of two corallites,
a, Central area;
b, Diameter of a corallite.

### PLATE XXIII.

Fig. 1. Transverse section of Cyathophyllum rugosum;
Fig. 2. Vertical section through the center of two corallites of Cyathophyllum rugosum. These specimens were exceedingly brittle and somewhat decomposed.
Fig. 3. Transverse section of Diphyllum strictum;
Fig. 4. Longitudinal section of same where two corallites are united.

### PLATE XXIV.

Fig. 1. Transverse section of Cyathophyllum caespetosum.
Fig. 2. Vertical section of same. This section is placed inverted on the Plate.
Fig. 3. Transverse section of Cyathophyllum panicum.
Fig. 4. Vertical section of same.

### PLATE XXV.

Fig. 1. Transverse section through one and partly through a second corallite of Strombodes pentagonis.
Fig. 2. Vertical section through the same.
Fig. 3. Photograph of a polished surface showing transverse section of Zaphrentis gigantea.
Fig. 4. Transverse section of a portion of a specimen given for Zaphrentis gigantea.

XXVI.

Fig. 1. Vertical section of a portion of the same specimen as the preceding.
Fig. 2. Transverse section of Zaphrentis spinulosa, with theca partially destroyed.
Fig. 3. Vertical section of the same.
Fig. 4. Transverse section of Lophophyllum proliferum with theca partially destroyed.
Fig. 5. Vertical section of the same.

PLATE XXVII.

Fig. 1. Transverse section of Streptelasma corniculum.
Fig. 3. Vertical section of the same.
Fig. 2. Transverse section of specimen 3 from Plate XIII. Fig. 2.

PLATE XXVIII.

Fig. 1. Vertical section of specimen 1, Plate XIII, Fig. 2.
Fig. 2. Vertical section of specimen 3, Plate XIII, Fig. 2.

PLATE XXIX.

Fig. 1. Transverse section of specimen 2, Plate XIII, Fig. 2,which agrees with the description Cystiphyllum.
Fig. 3. Vertical section of same specimen.
Fig. 2. Transverse section through several corallites of Calapoecia cricriformis (Plate XIV, Fig. 2).

PLATE XXX.

Fig. 1. Vertical section of same specimen as the preceding.
Fig. 2. Transverse section through a number of corallites of specimen Plate XV, Fig. 1.
Fig. 3. Vertical section through several corallites of the same specimen as the preceding.

PLATE XXXI.

Fig. 1. Vertical section through a number of corallites of Favosites forbesi, Var. occidentalis, p.p. intramural pores.
Fig. 2. Transverse section of the same; p.p. intramural pores.
Fig. 3. Transverse section of Favosites goldfussi, p.p. intramural pores.
Fig. 4. Vertical section of the same. p.p. pores.
Fig. 5. The facial view of a few individuals of Favosites goldfussi.
Fig. 6. Transverse section of a specimen of Favosites hamiltoniae p.p. pores; sp. spinules indicating the septae.

PLATE XXXII.

Fig. 1. Vertical section of the same as the preceding,p.p.pores.
Fig. 2. Transverse section of Favosites niagarensis (small corallites)
Fig. 3. Vertical section of same.
Fig. 4. Vertical section of Favosites niagarensis (large corallites).
Fig. 5. Transverse section of same.
Fig. 6. Vertical section through two corallites of Syringopora maclurii.

PLATE XXXIII.

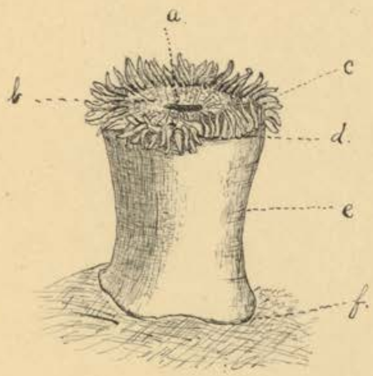
Fig. 1. Vertical section through Emmonsia hemispherica.
Fig. 2. Transverse section through the same, though somewhat angling.
Fig. 3. Transverse section of Syringopora tabulata.
Fig. 4. Vertical section of Syringopora tabulata.

PLATE XXXIV.

Fig. 1. Transverse section of Heliolites intersticus (Plate XX.Fig. 1).
Fig. 2. Vertical section of same.
Fig. 3. Transverse section of Halysites catenulatus.
Fig. 4. Vertical section of same.

PLATE XXXV.

Fig. 1. Transverse section of Tetradium minimus.
Fig. 2. Vertical section of same.
Fig. 3. Transverse section of Tetradium fibratum.
Fig. 4. Vertical section of same.

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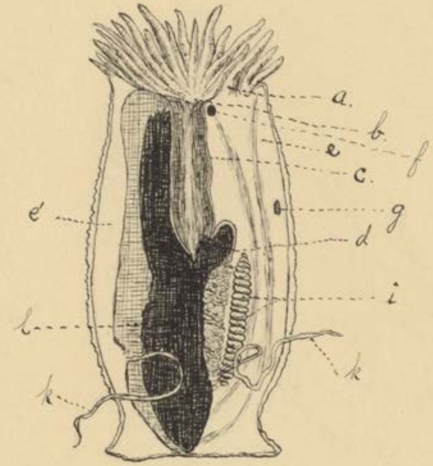


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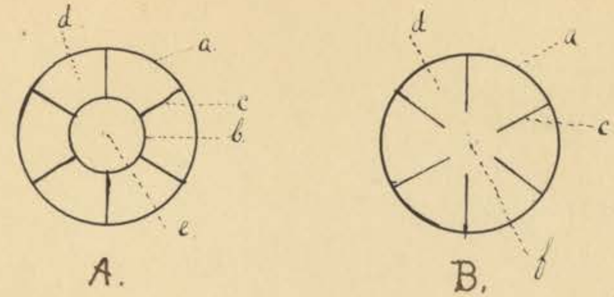


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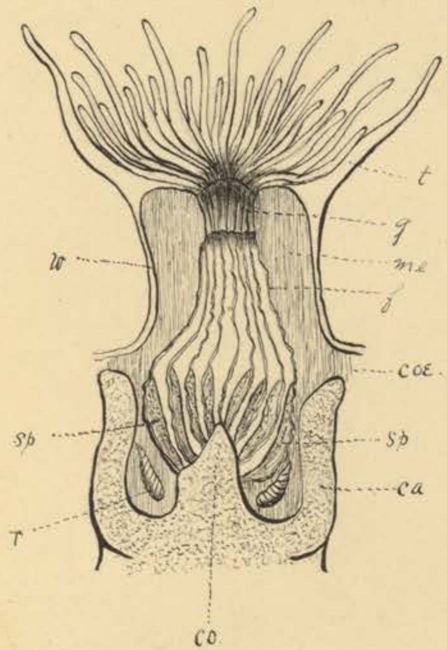



Fig. 2.

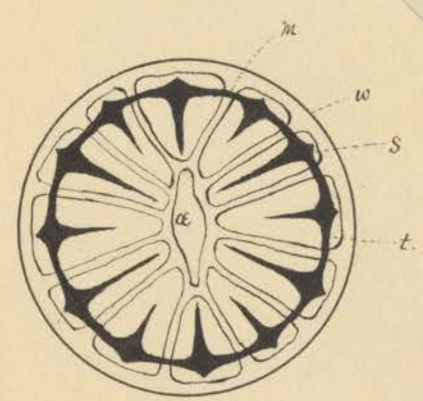



Fig. 3.

Plate III.

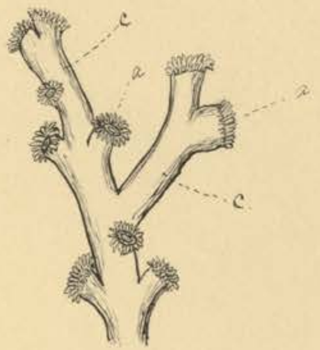



Fig. 1

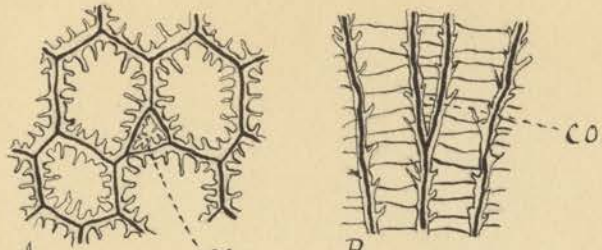



Fig. 2.

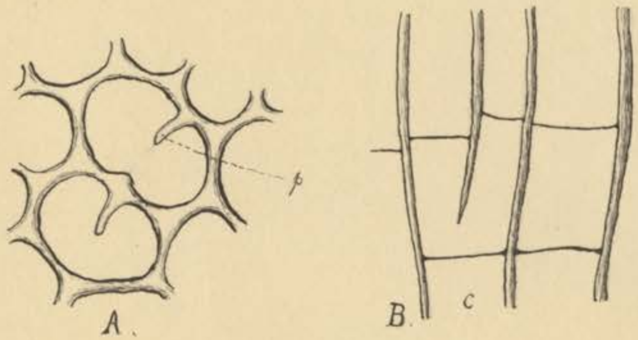



Fig. 3.

Plate IV.


Fig. 1. Cyathophyllum houghtoni.

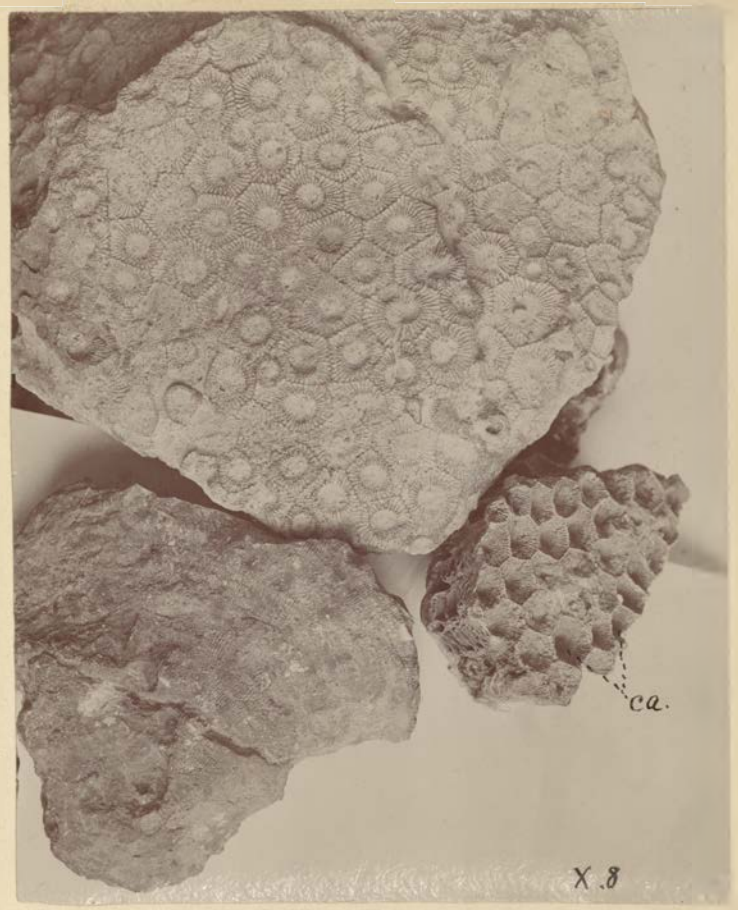



Fig. 2. Cyathophyllum davidsoni.

Plate V.



Fig. 1. Cyathophyllum rugosum.

Fig. 2.

Plate VI.


Fig. 1. Diphyphyllum strictum.


Fig. 2. Lithostrotion canadense.


Fig.1. Lithostrotion proliferum.


Fig.2. Strombodes pentagonis.

Plate VIII.


Fig. 1. Zaphrentis gigantea.


Fig. 2. Zaphrentis cornicula.


Fig. 1. Zaphrentis dalei.

Fig. 2. Zaphrentis prolifica.

Plate X.


Fig. 1. Zaphrentis spinulosa.


Fig. 2. Zaphrentis calceola.

Plate XI.



Fig.1. Amplexus yandelli.

Fig.2. Lophophyllum proliferum.


Fig. 1. Hadrophyllum orbignyi.


Fig. 2. Streptelasma corniculum.

Plate XIII:


Fig. 1. Cystiphyllum vesiculosum.


Fig. 2 Cystipayllum americanum.


Fig. 1. Protarea vetusta.


Fig. 2. Calapoecia cribriformis.

Plate XV.


Fig. 1. Calapoecia cribriformis.


Fig. 2. Favosites forbesi, var. occidentalis.


Fig. 1. Favosites goldfussi.

Fig. 2. Favosites polymorphus.

Plate XVII.

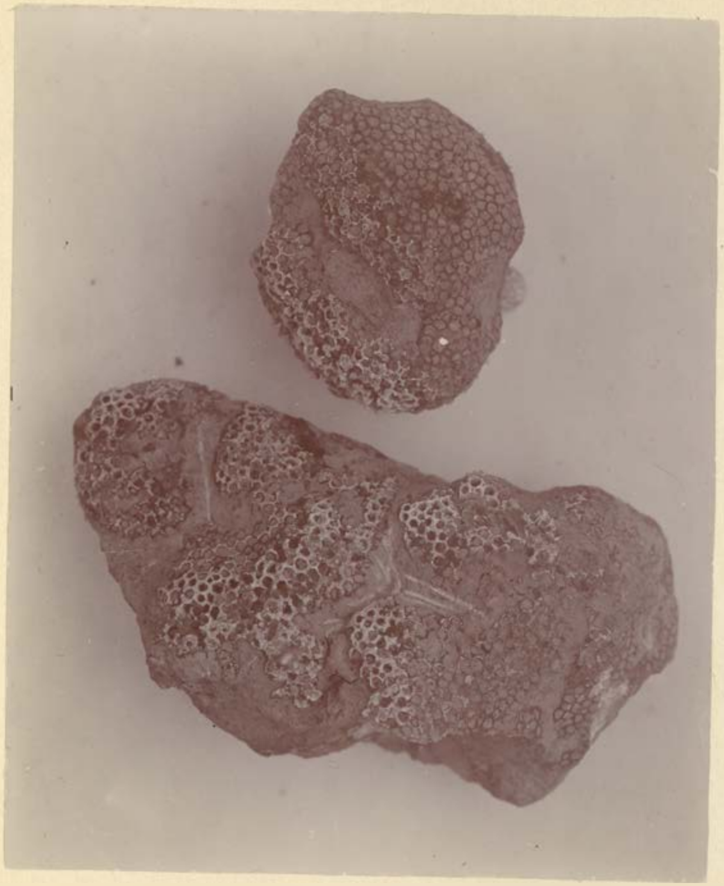


Fig. 1. Favosites hamiltoniae.

Fig. 2. Favosites niagarensis. (large corallites).

Plate XVIII.


Fig. 1. Emmonsia hemispherica.

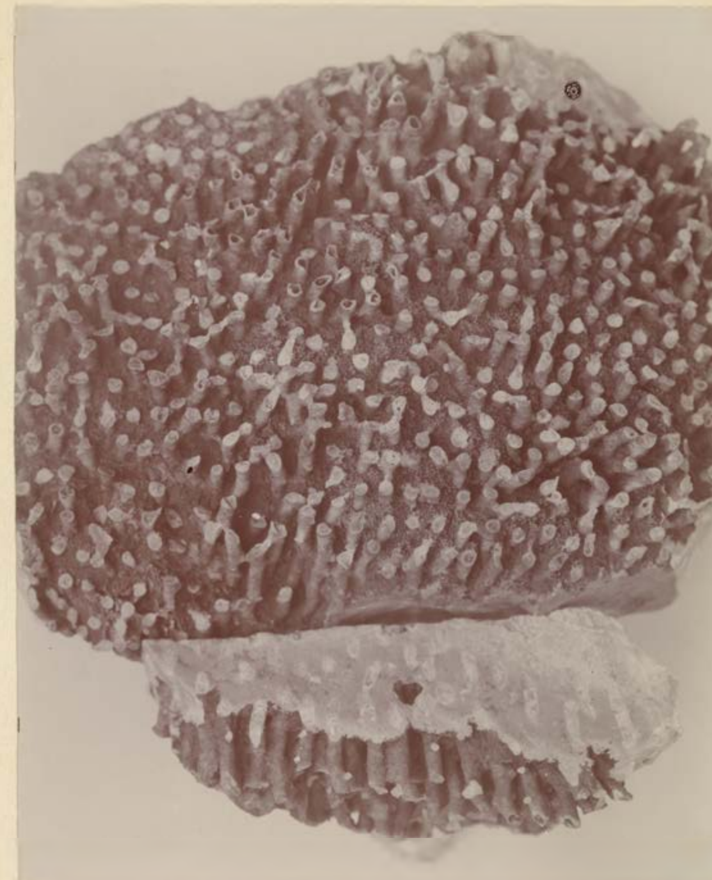


Fig. 2. Syringopora maclurii.

Plate XIX.

Fig. 1. Syringopora tabulata.


Fig. 2. Heliolites interstinctus.

Plate XX.

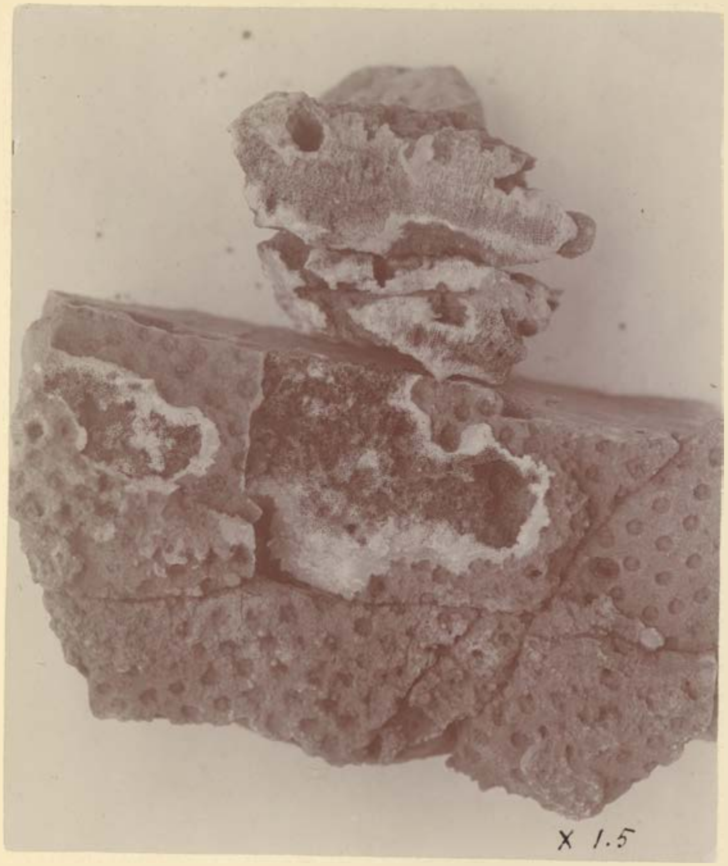



Fig. 1. Heliolites interstinctus.


Fig. 2. Halysites catenulatus.

Plate XXI.


Fig. 1. Tetradium fibratum.

Plate XXII.

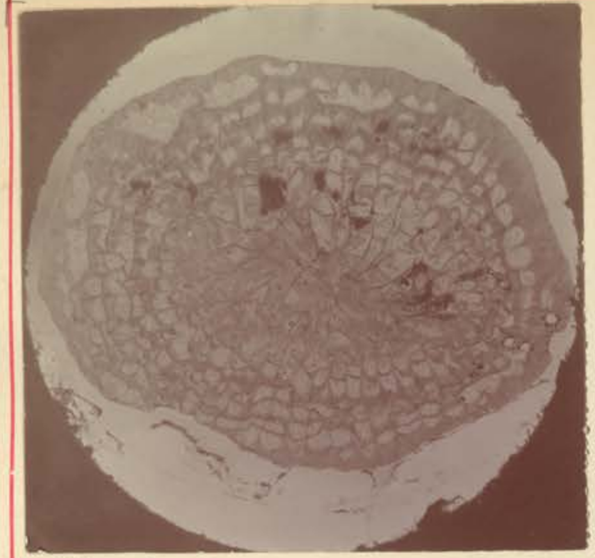
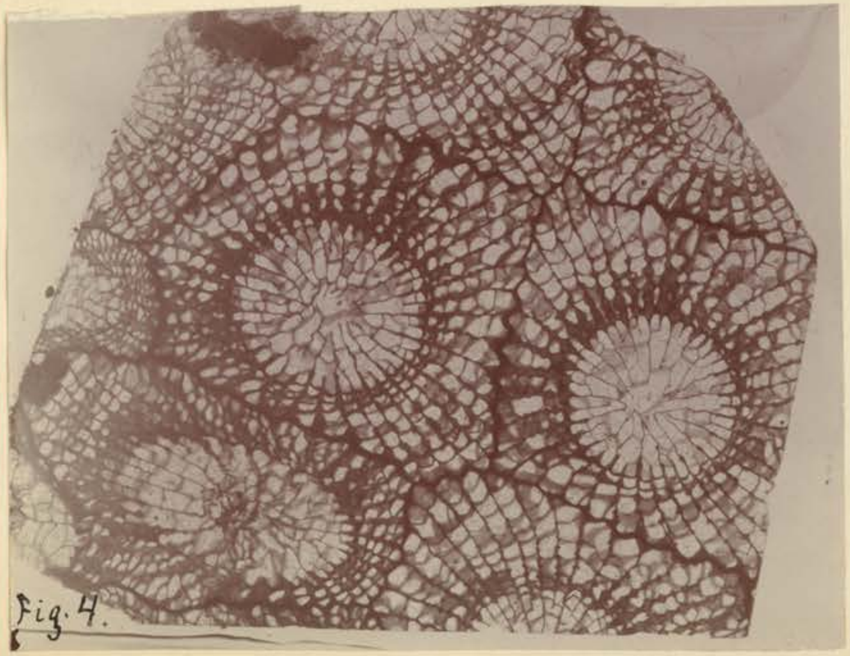


Fig. 1.

Fig. 2.

Fig. 3.



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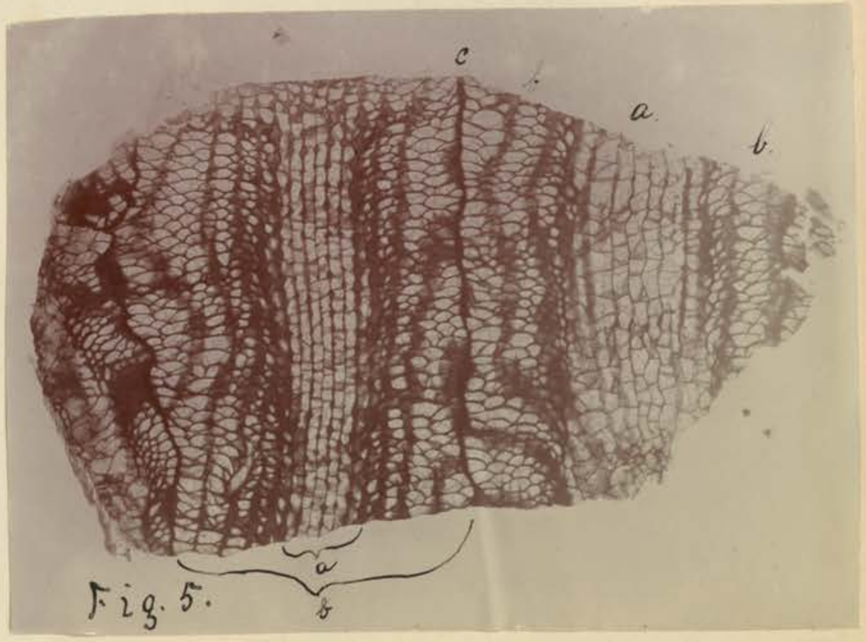


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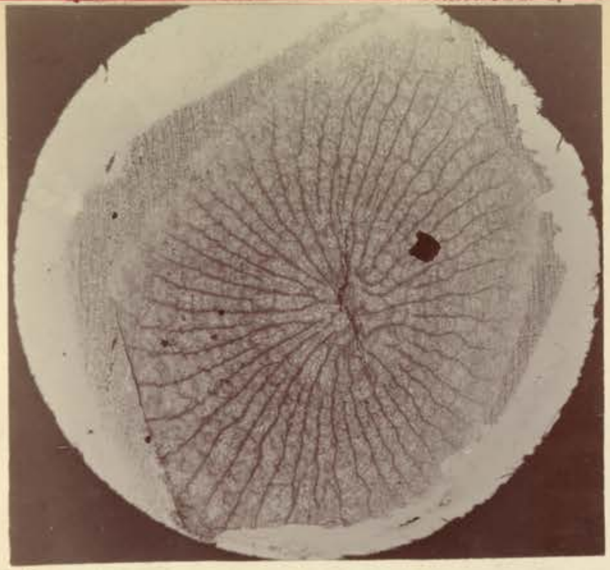

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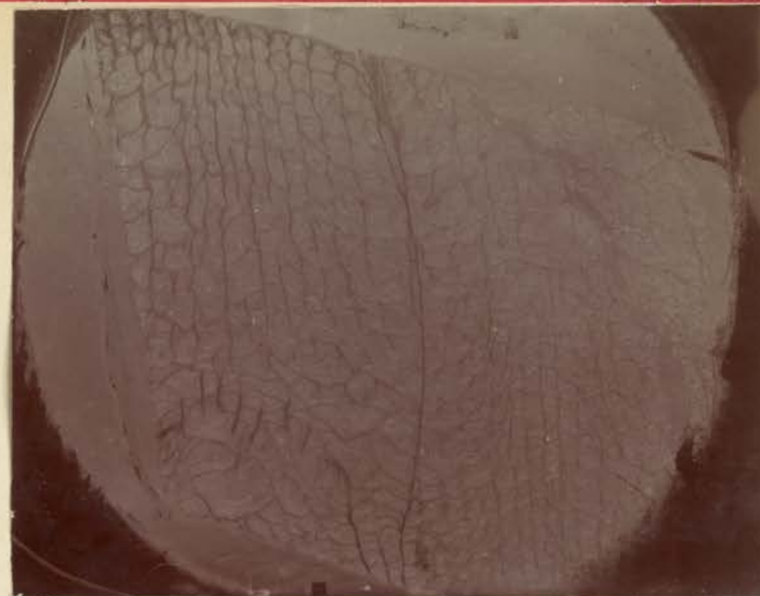
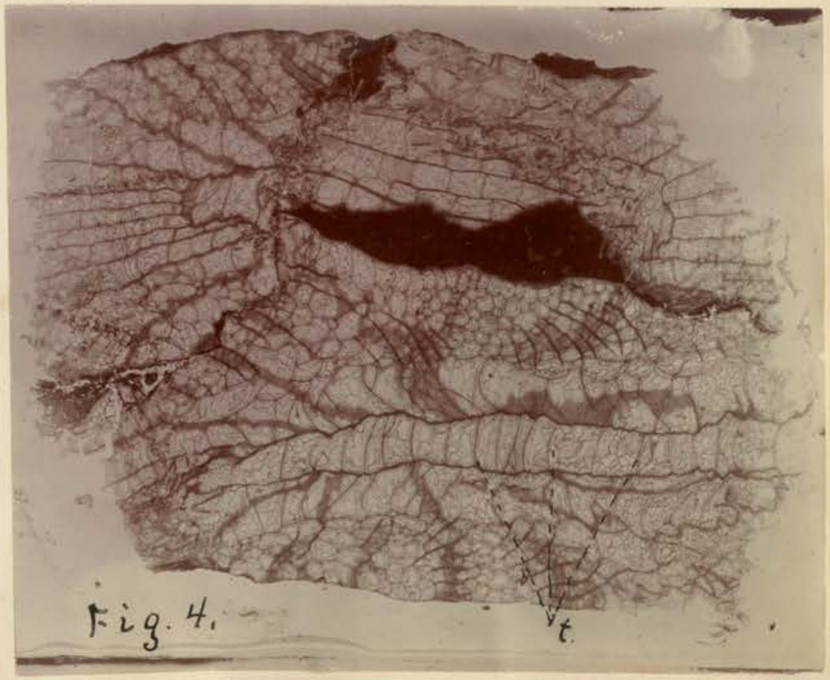


Fig. 2.

Fig. 3.

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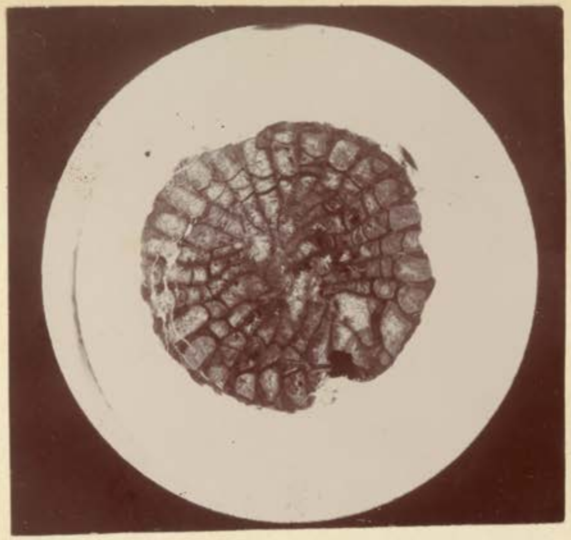

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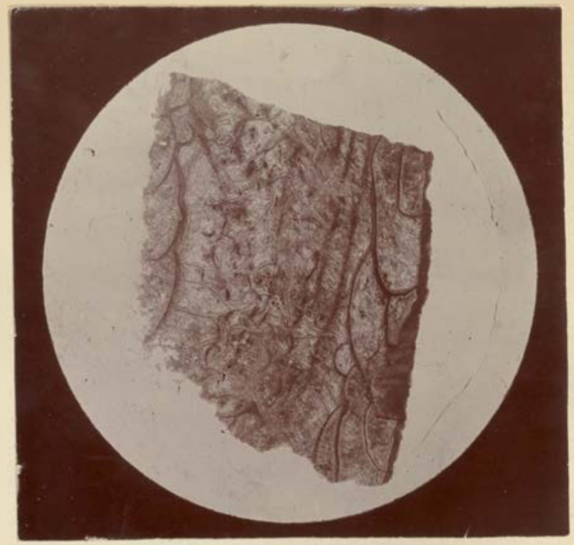

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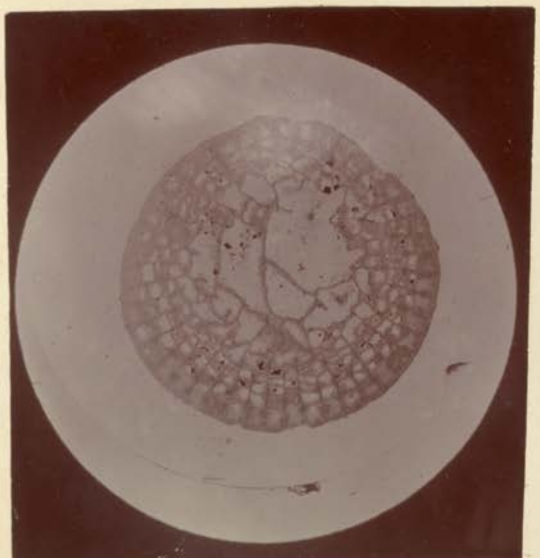


Fig. 3.

Fig. 4.

Plate XXV.

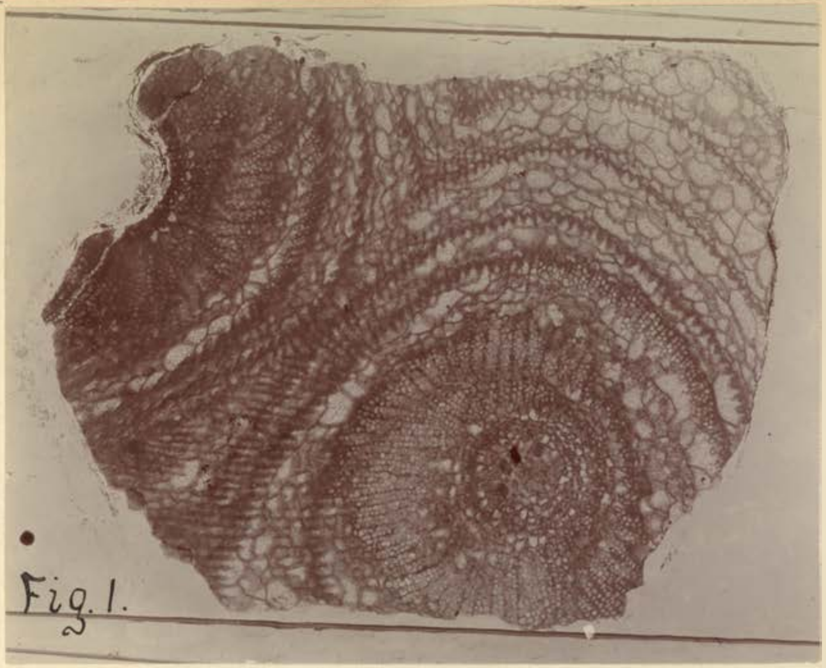


Fig. 1.

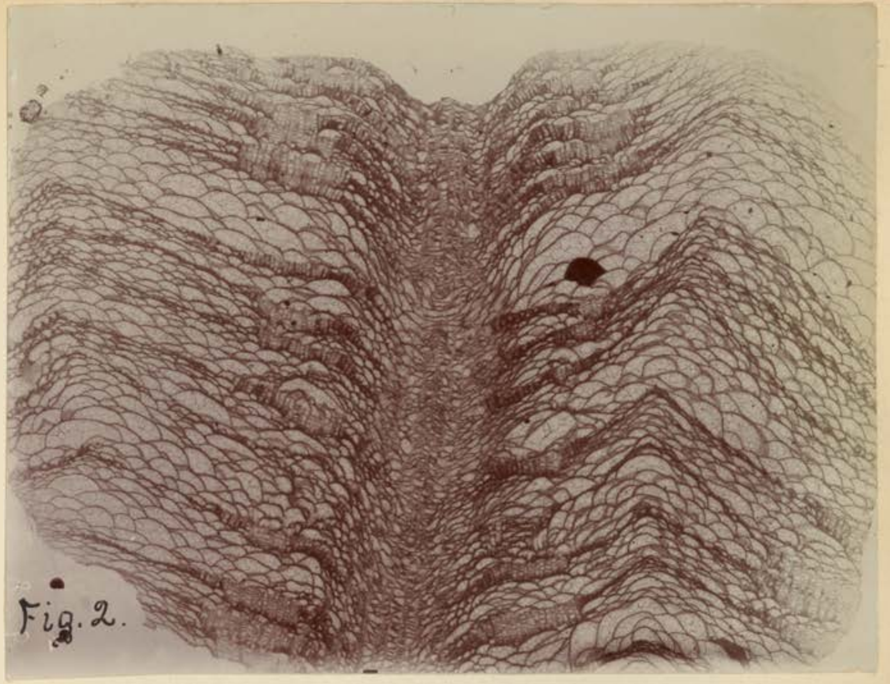
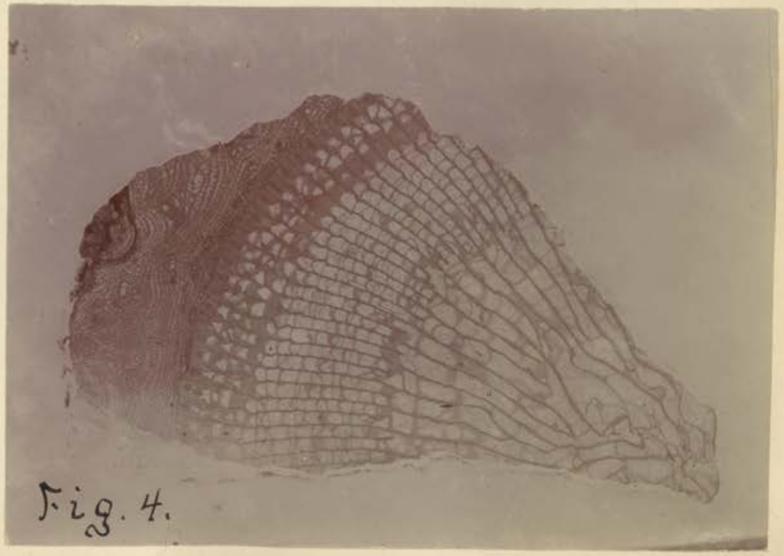


Fig. 2.

Fig. 3



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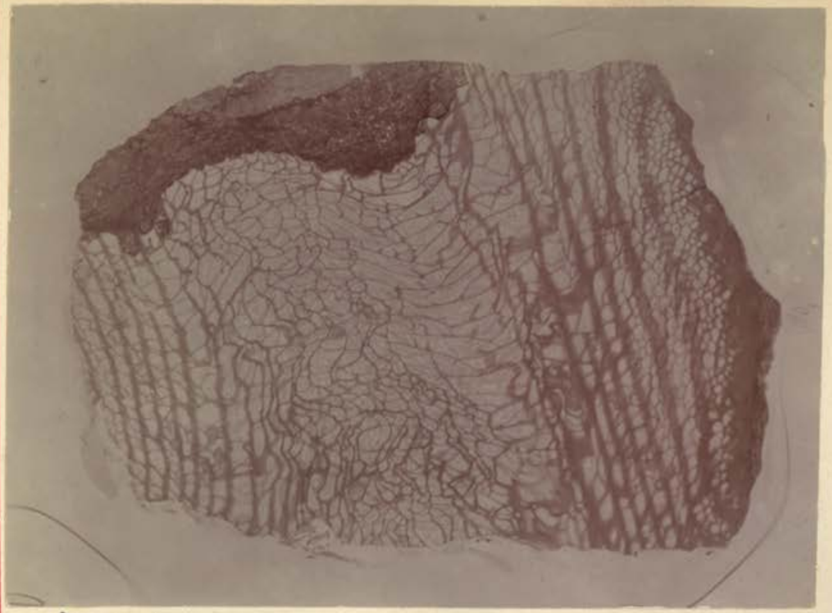


Fig. 1.

Fig. 2.

Fig. 3.

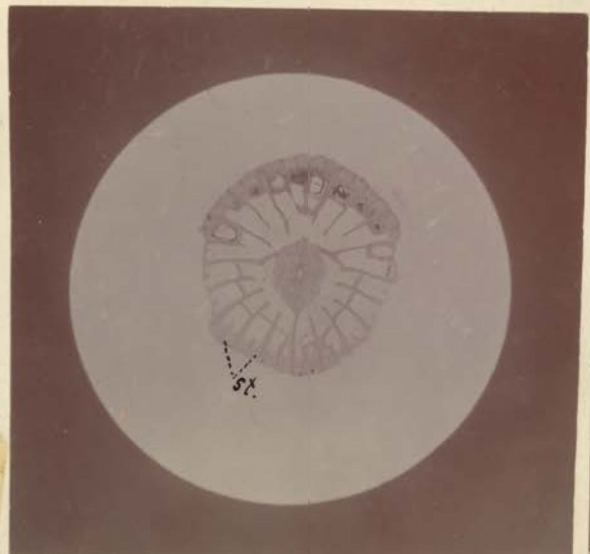
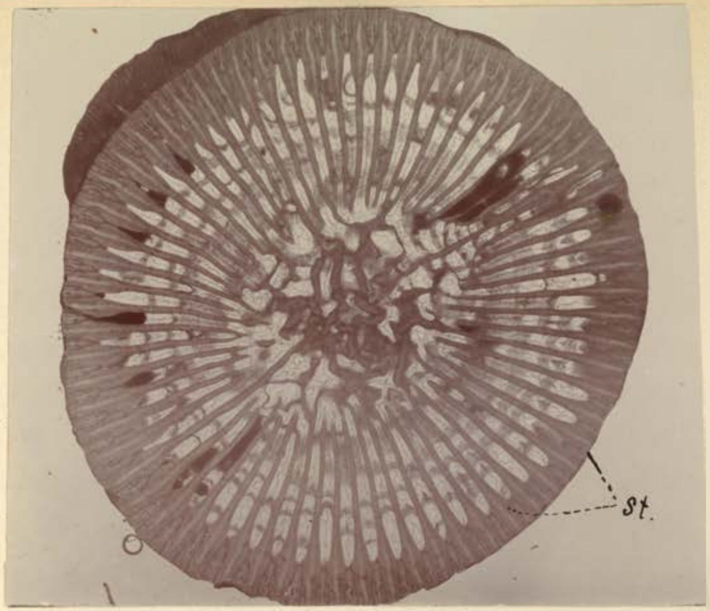



Fig. 4.


Fig. 5.

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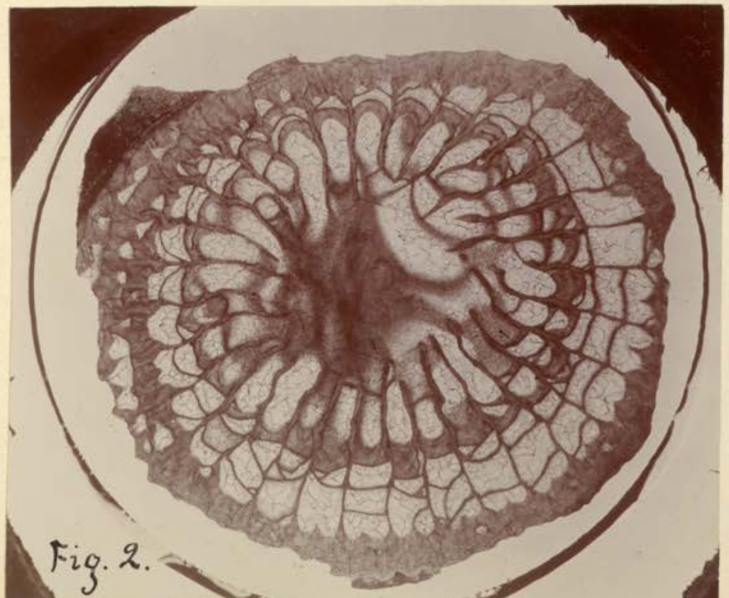


Fig. 2.

Fig. 3.

Plate XXVIII.


Fig. 1.

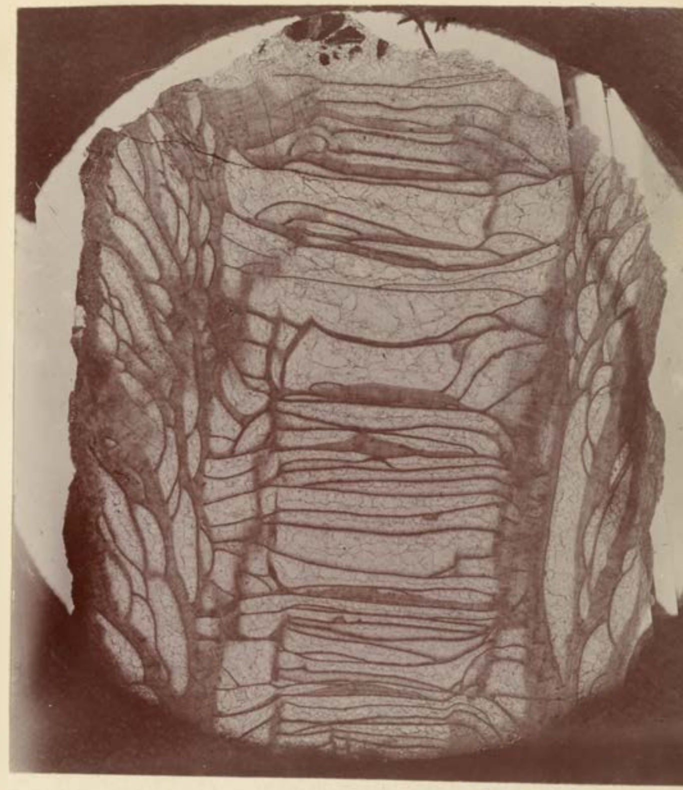
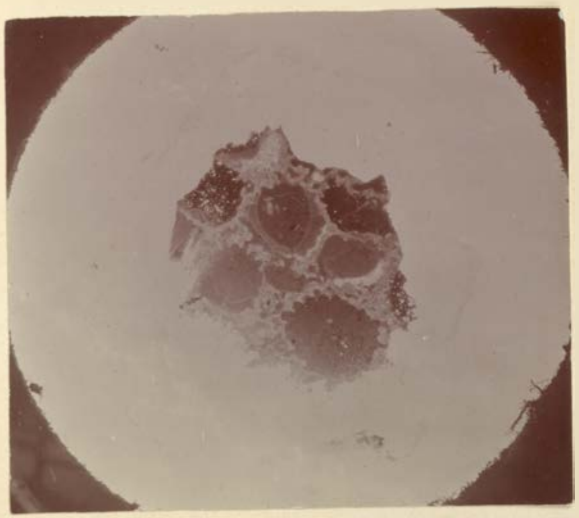


Fig. 2.

Plate XXIX.

Fig. 1.



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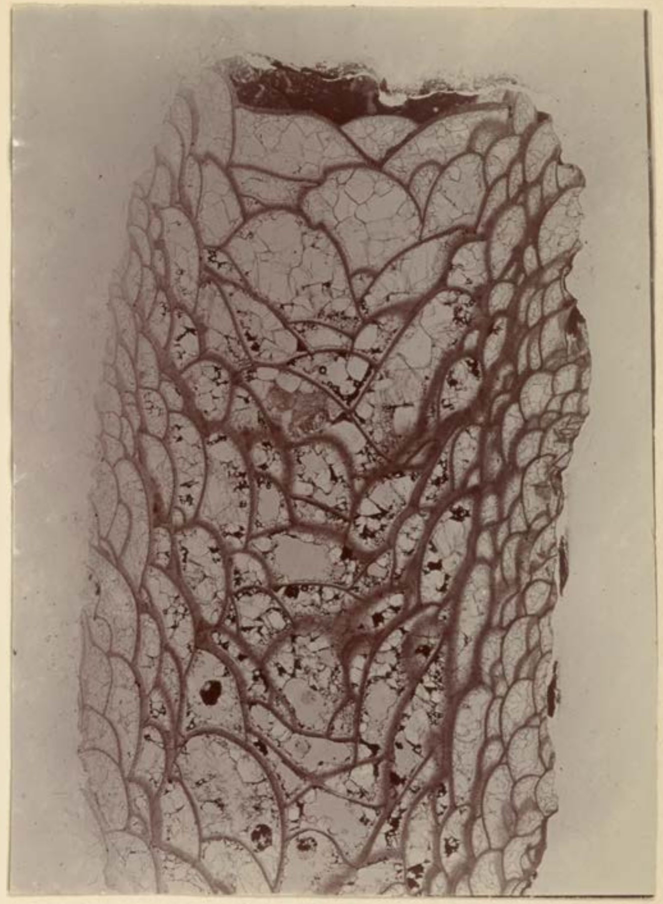

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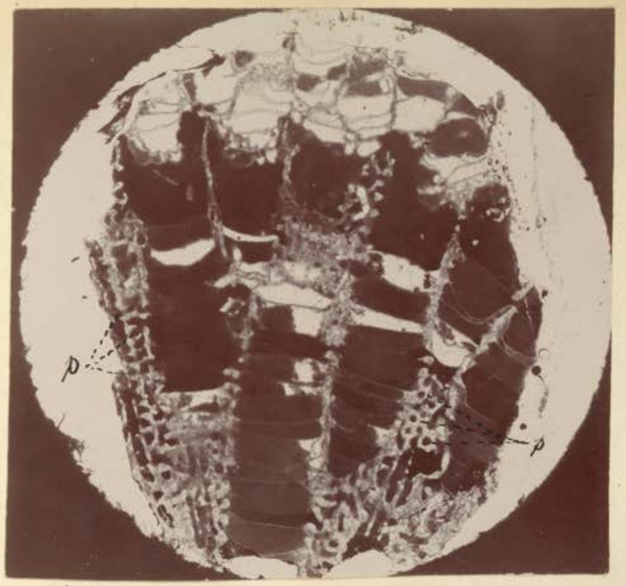


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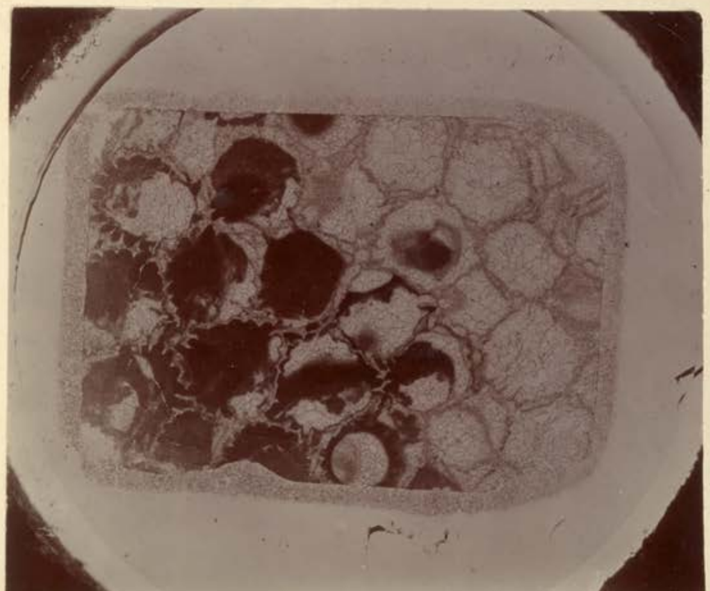

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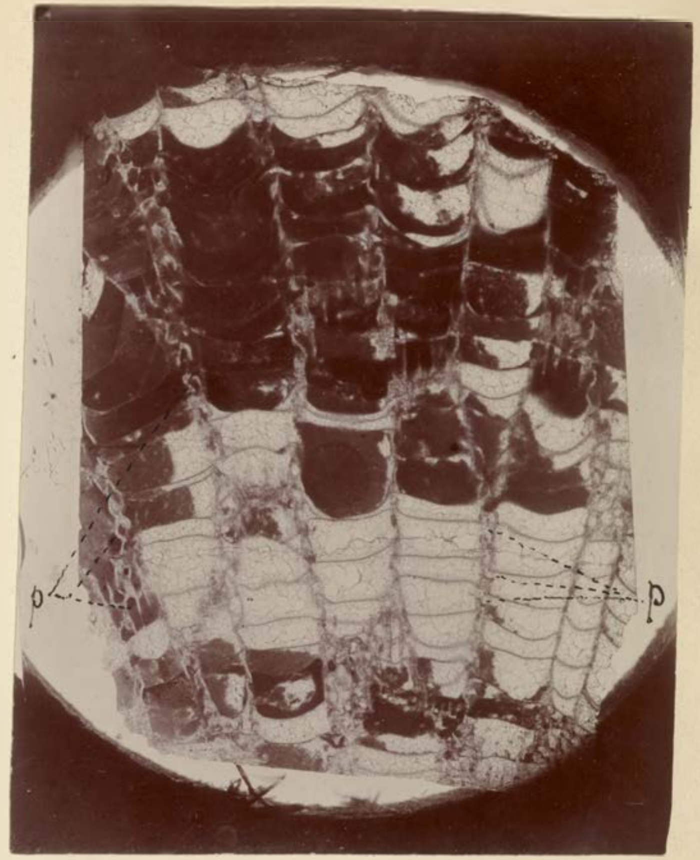



Fig. 3.

Plate XXXI.


Fig. 1.


Fig. 2.

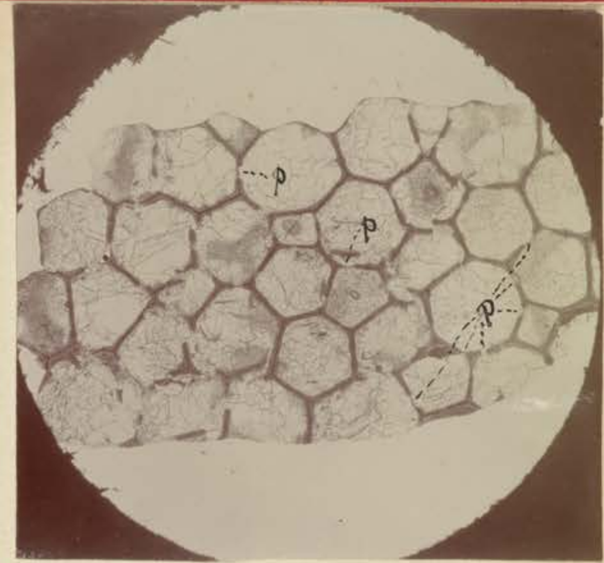



Fig. 3.

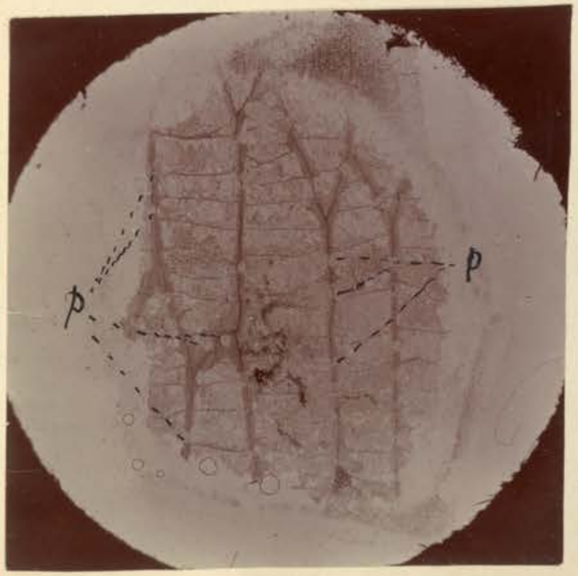
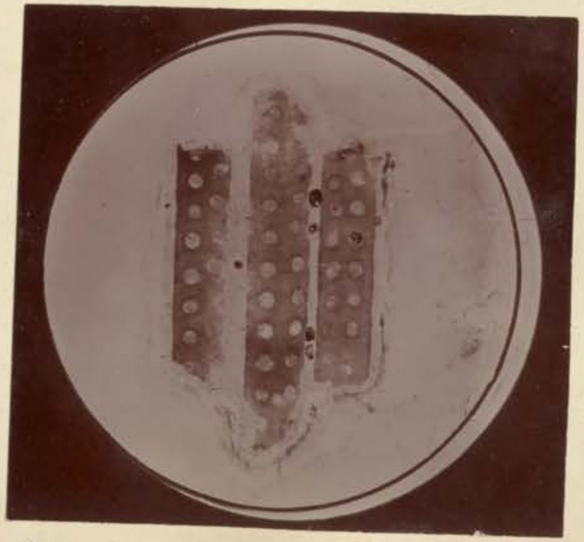



Fig. 4.



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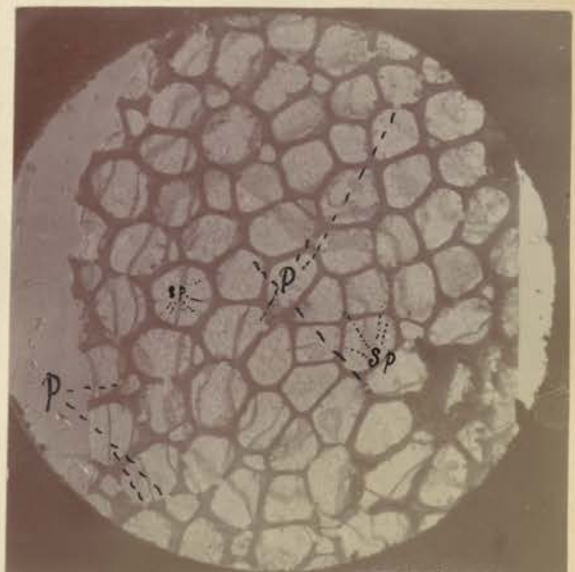


Fig. 6.

Plate XXXII.


Fig. 1.

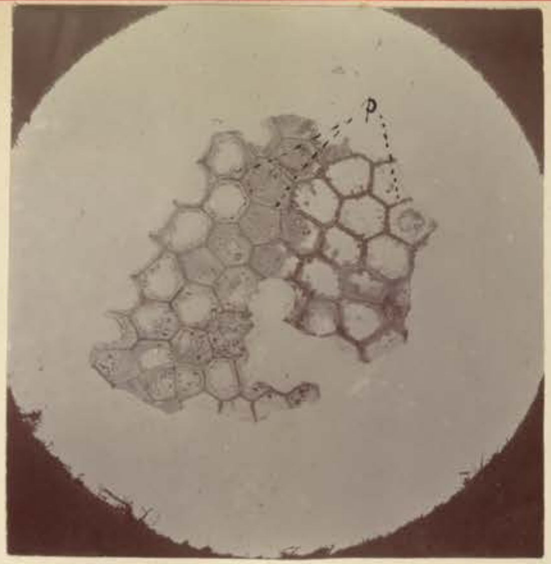


Fig. 2.

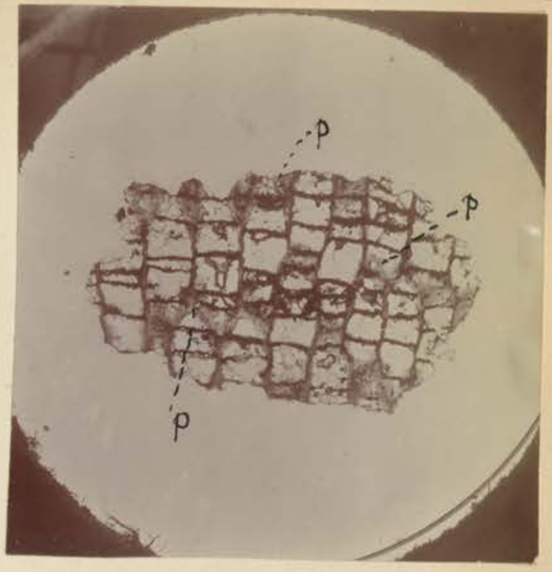


Fig. 3.

Fig. 4.

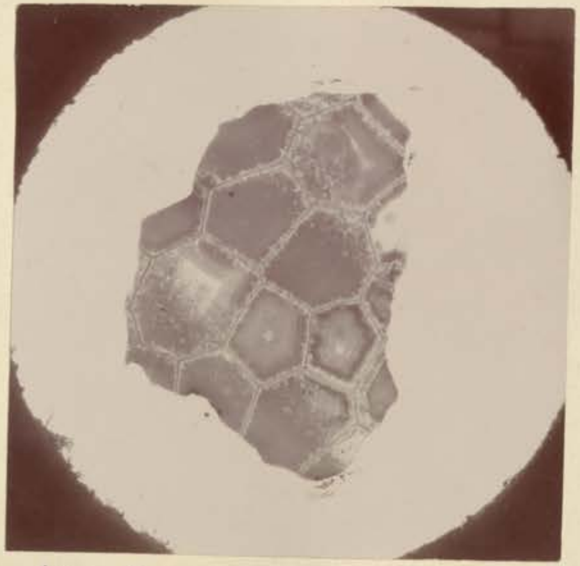

Fig. 5.

Fig. 6.

Plate XXXIII.

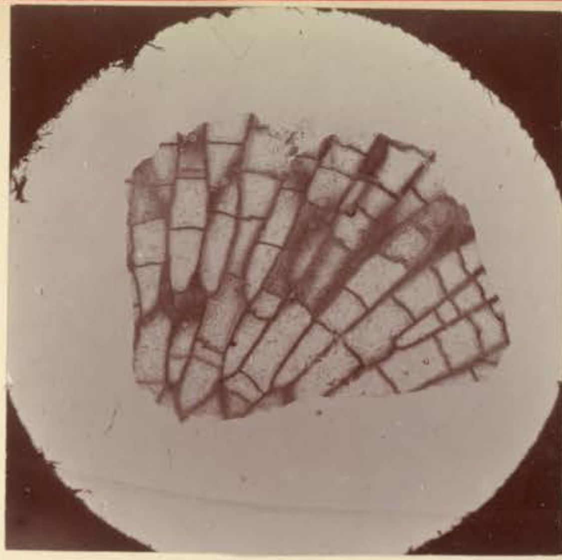

Fig. 1.

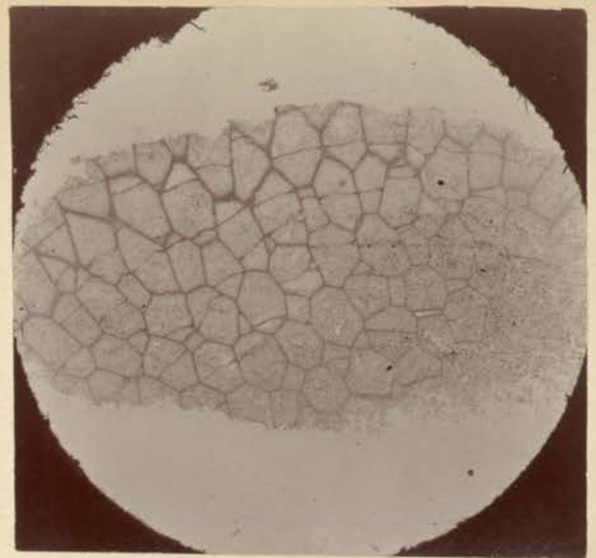

Fig. 2.

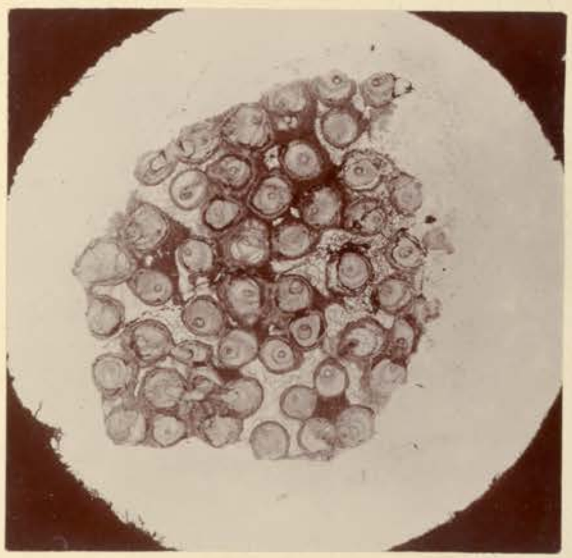

Fig. 3.

Fig. 4.

Plate XXXIV.

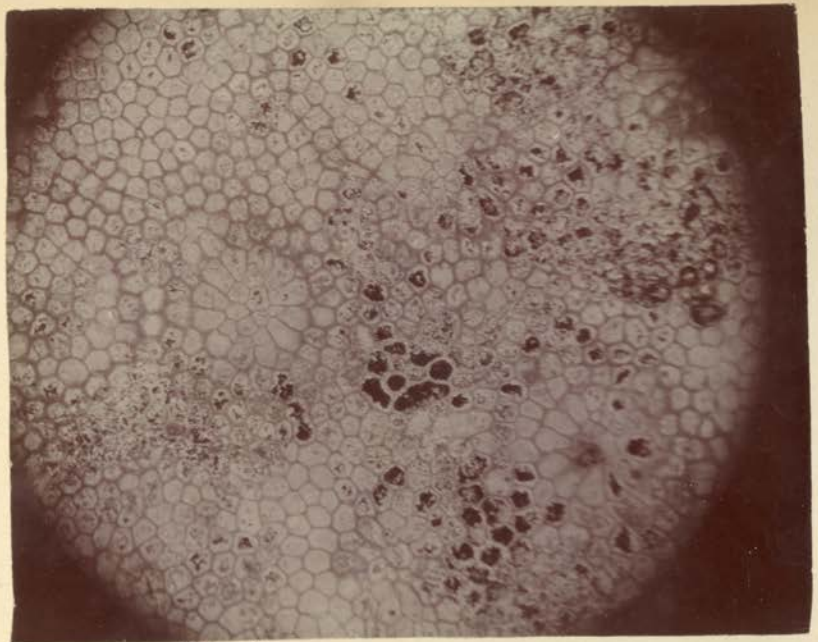

Fig. 1.

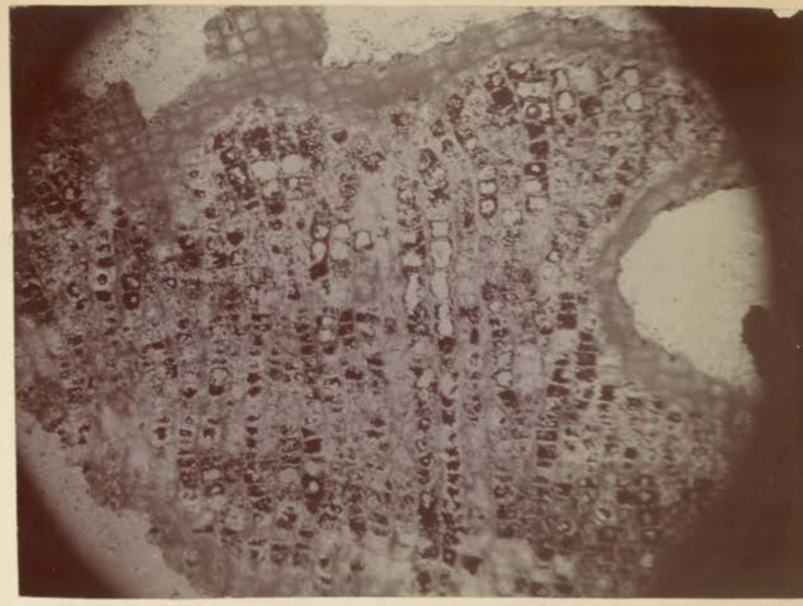

Fig. 2.

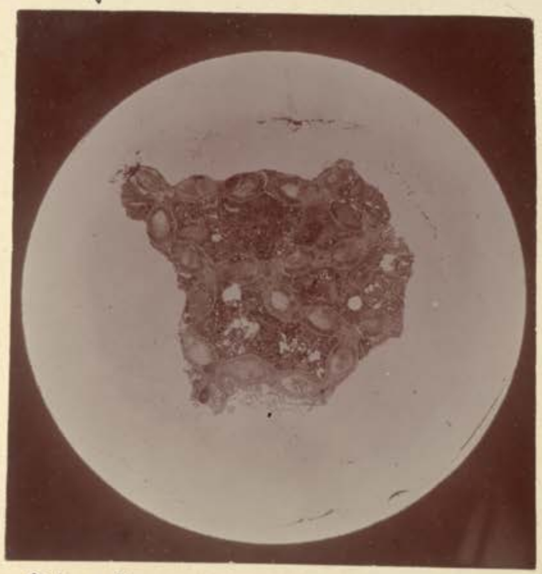

Fig. 3.

Fig. 4.

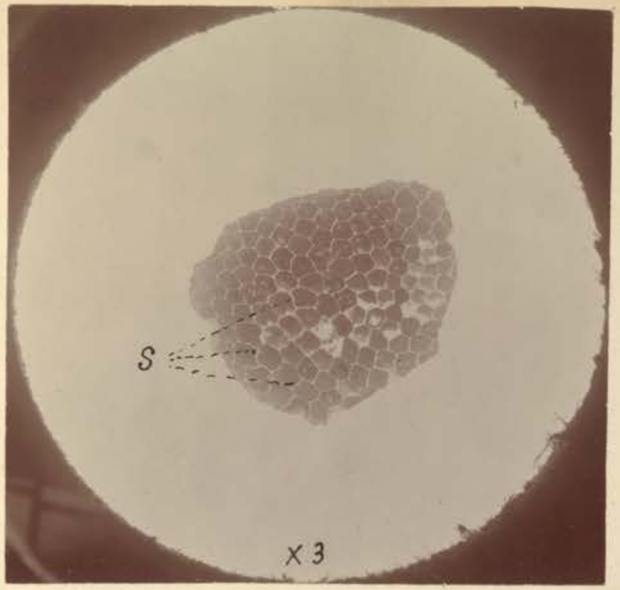


Fig. 1.

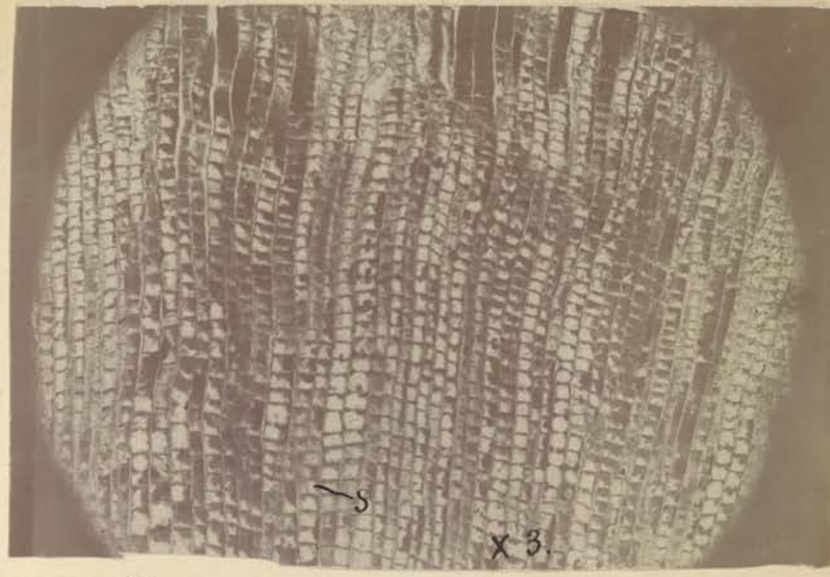


Fig. 2.

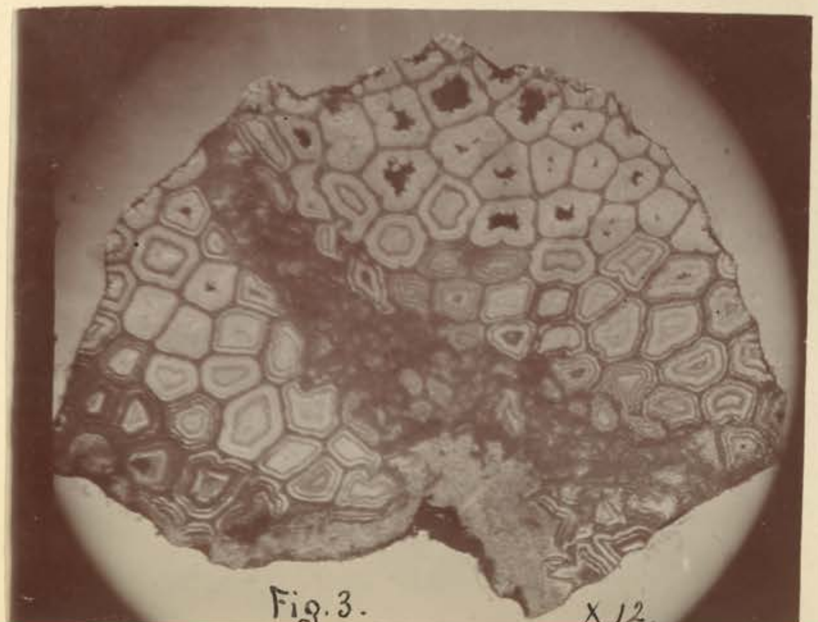


Fig. 3.

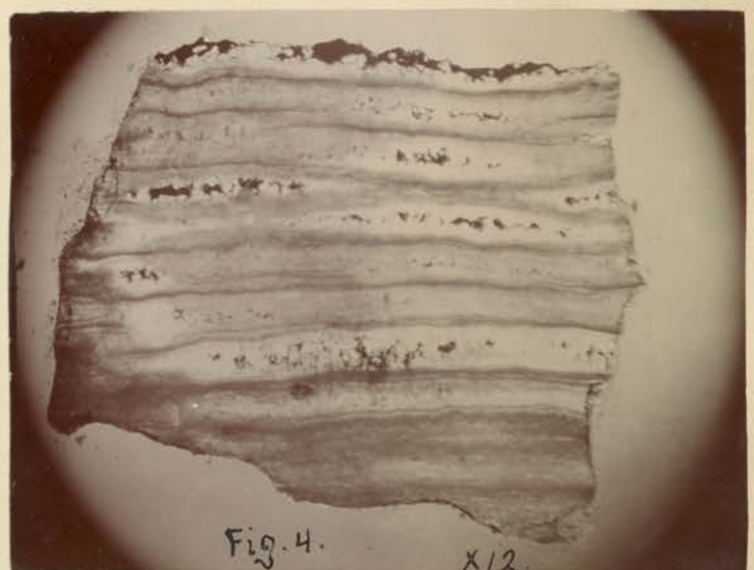


Fig. 4.

R

D50 Illuminant, 2 degree observer

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| L* = | 38.12 | 65.43 | 49.87 | 44.26 | 55.56 | 70.82 | 63.51 | 39.02 | 52.24 |
| a* = | 13.24 | 18.11 | -4.34 | -13.80 | 9.82 | -33.43 | 34.26 | 11.81 | 48.55 |
| b* = | 15.07 | 18.72 | -22.29 | 22.85 | -24.49 | -0.35 | 59.60 | -46.07 | 18.51 |

| | 10 | 11 (A) | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|
| L* = | 97.06 | 92.02 | 87.34 | 82.14 | 72.06 | 62.15 |
| a* = | -0.40 | -0.60 | -0.75 | -1.06 | -1.19 | -1.07 |
| b* = | 1.12 | 0.23 | 0.21 | 0.43 | 0.28 | 0.19 |
| Density = | 0.04 | 0.09 | 0.15 | 0.22 | 0.36 | 0.51 |

| | 16 (M) | 17 | 18 (B) | 19 | 20 | 21 |
|---|---|---|---|---|---|---|
| L* = | 49.25 | 38.62 | 28.86 | 16.19 | 8.29 | 3.44 |
| a* = | -0.18 | -0.18 | 0.54 | -0.05 | -0.81 | -0.23 |
| b* = | 0.01 | -0.04 | 0.60 | 0.73 | 0.19 | 0.49 |
| Density = | 0.75 | 0.98 | 1.24 | 1.87 | 2.04 | 2.42 |

| | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|
| L* = | 31.41 | 72.46 | 72.95 | 29.37 | 54.91 | 43.06 | 82.74 | 52.79 | 50.87 |
| a* = | 20.98 | -24.45 | 16.83 | 13.06 | -38.91 | 52.00 | 3.45 | 50.88 | -27.17 |
| b* = | -19.43 | 55.93 | 68.80 | -49.49 | 30.77 | 30.01 | 81.29 | -12.72 | -29.46 |

Colors by Munsell Color Services Lab

Golden Thread

Version# DL1.0

Don Williams

R

D50 Illuminant, 2 degree observer

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| L* = | 39.12 | 65.43 | 49.87 | 44.26 | 55.56 | 70.82 | 63.51 | 39.92 | 52.24 |
| a* = | 13.24 | 18.11 | -4.34 | -13.80 | 9.82 | -33.43 | 34.26 | 11.81 | 48.55 |
| b* = | 15.07 | 18.72 | -22.29 | 22.85 | -24.49 | -0.35 | 59.60 | -46.07 | 18.51 |

| | 10 | 11 (A) | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|
| L* = | 97.00 | 92.02 | 87.34 | 82.14 | 72.06 | 62.15 |
| a* = | -0.40 | -0.60 | -0.75 | -1.06 | -1.19 | -1.07 |
| b* = | 1.13 | 0.23 | 0.21 | 0.43 | 0.28 | 0.19 |
| Density = | 0.04 | 0.08 | 0.15 | 0.22 | 0.36 | 0.51 |

| | 16 (M) | 17 | 18 (B) | 19 | 20 | 21 |
|---|---|---|---|---|---|---|
| L* = | 49.25 | 38.62 | 28.86 | 16.19 | 8.29 | 3.44 |
| a* = | -0.16 | -0.18 | 0.54 | -0.05 | -0.81 | -0.23 |
| b* = | 0.01 | -0.04 | 0.60 | 0.73 | 0.19 | 0.49 |
| Density = | 0.75 | 0.98 | 1.24 | 1.67 | 2.04 | 2.42 |

| | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|
| L* = | 31.41 | 72.46 | 72.95 | 29.37 | 54.91 | 43.96 | 82.74 | 52.79 | 50.87 |
| a* = | 20.98 | -24.45 | 16.83 | 13.06 | -38.91 | 52.00 | 3.45 | 50.88 | -27.17 |
| b* = | -19.43 | 55.93 | 68.80 | -49.49 | 30.77 | 30.01 | 81.29 | -12.72 | -29.46 |

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